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FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. LXIX. MAY, 1875. No. 5.

EDITORIAL.

ITEMS AND NOVELTIES.

The United States Commission on Tests of Iron, Steel, etc.—The Congress of the United States made provision as is well known, by an Act approved March 3d, 1875, for the appointment by the President of a Commission to experiment and report upon the metals used in construction, the commission to be composed of men eminent in the specified direction. An appropriation of $50,000 was made to defray the expenses of this commission. In accordance with this Act of Congress, the President appointed Commander L. A, Beardslee, U.S.N., well known for his investigations on tensile strains, Lieut. Col. Q. A. Gillmore, U.S.A., the eminent military engineer, A. L. Holley, C.E., whose reputation as a metallurgical engineer is national, Lieut. Col. T. T. S. Laidley, U.S.A., the accomplished commandant of the arsenal at Watertown, Mass., Chief Engineer David Smith, U.S.N., a man pre-eminent among dynamic engineers, W. Sooy Smith, C.E., and Prof. R. H. Thurston, C.E., who has, by his new testing machine, revolutionized the theory of strength of materials, as the members of this commission. A meet-

ing for organization was held at the Watertown Arsenal, and at that meeting, Lt. Col. T. T. S. Laidley was elected President of the Commission, and Professor R. H. Thurston, Secretary. In one of the circulars they have issued, the statement is made that the commission "is instructed to determine by actual tests the strength and value of all kinds of iron, steel, and other metals which may be submitted to it, or by it procured, and to prepare tables which will exhibit the strength and value of said materials for constructive purposes."

In a second circular, they say:—

"The Commission desires to secure the assistance of all who are interested in this great work, and through them to obtain all information available as the result of the labors of earlier, or of contemporaneous, investigators and observers. I take the liberty of enclosing herewith circulars indicating the scope of the labors undertaken by this Commission, and beg that you will aid, by such methods as may be by you deemed best, in the collection of all information which may be accessible, relating to either the general work of the Commission or to the special subjects assigned to its committees. Data collected in the course of ordinary business practice, and the records of special researches previously made or now in progress, are particularly desired.

"It is expected that the Commission will receive valuable information and useful suggestions, both from business men and from men of science, and it is hoped that the work undertaken, as here indicated, may be supplemented by original investigations made by both these classes. The national importance of this work justifies the expectation of an earnest and effective co-operation.

"Very respectfully yours,

"R. H. THURSTON,

"*Secretary.*"

The following are the Standing Committees of the Board.

(A.) On Abrasion and Wear.—R. H. Thurston, C.E., Chairman, A. L. Holley, C.E., Chief Engineer D. Smith, U.S.N.

Instructions.—To examine and report upon the abrasion and wear of railway wheels, axles, rails and other materials, under the conditions of actual use.

(B.) On Armor Plate.—Lt. Col. Q. A. Gillmore, U.S.A., Chairman, A. L. Holley, C.E., R. H. Thurston, C.E.

Instructions.—To make tests of Armor Plate, and to collect data derived from experiments already made to determine the characteristics of metal suitable for such use.

(C.) On Chemical Research.—A. L. Holley, C.E., Chairman, R. H. Thurston, C.E.

Instructions.—To plan and conduct investigations of the mutual relations of the chemical and mechanical properties of metals.

(D.) On Chains and Wire Ropes.—Commander L. A. Beardslee, U.S.N., Chairman, Lt. Col. Q. A. Gillmore, U.S.A., Chief Engineer D. Smith, U.S.N.

Instructions.—To determine the character of iron best adapted for chain cables, the best form and proportions of link, and the qualities of metal used in the manufacture of iron and steel wire rope.

(E.) On Corrosion of Metals.—W. Sooy Smith, C.E., Chairman, Lt. Col. Q. A. Gillmore, U.S.A., Commander L. A. Beardslee, U.S.A.

Instructions.—To investigate the subject of the corrosion of metals under the conditions of actual use.

(F.) On the Effects of Temperature.—R. H. Thurston, C.E., Chairman, Lt. Col. Q. A. Gillmore, U.S.A., Commander L. A. Beardslee, U.S.N.

Instructions.—To investigate the effects of variations of temperature upon the strength and other qualities of iron, steel, and other metals.

(G.) On Girders and Columns.—W. Sooy Smith, C. E., Chairman, Lt. Col. Q. A. Gillmore, U. S. A., Chief Eng'r D. Smith, U. S. N.

Instructions.—To arrange and conduct experiments to determine the laws of resistance of beams, girders and columns to change of form and to fracture.

(H.) On Iron, Malleable.—Commander L. A. Beardslee, U. S. N., Chairman, W. Sooy Smith, C. E., A. L. Holley, C. E.

Instructions.—To examine and report upon the mechanical and physical proportions of wrought iron.

(I.) On Iron, Cast.—Lt. Col. Q. A. Gillmore, U.S.A., Chairman, R. H. Thurston, C.E., Chief Eng'r D. Smith, U.S.N.

Instructions.—To consider and report upon the mechanical and physical properties of cast iron.

(J.) On Metallic Alloys.—R. H. Thurston, C.E., Chairman, Commander L. A. Beardslee, U.S.N., Chief Eng'r D. Smith, U.S.N.

Instructions.—To assume charge of a series of experiments on the characteristics of alloys, and an investigation of the laws of combination.

(K.) On Orthogonal Simultaneous Strains.—W. Sooy Smith, C.E., Chairman, Commander L. A. Beardslee, U.S.N., R. H. Thurston, C. E.

Instructions.—To plan and conduct a series of experiments on simultaneous orthogonal strains, with a view to the determination of laws.

(L.) On Physical Phenomena.—W. Sooy Smith, C.E., Chairman, A. L. Holley, C.E., R. H. Thurston, C.E.

Instructions.—To make a special investigation of the physical phenomena accompanying the distortion and rupture of materials.

(M.) On Re-Heating and Re-Rolling.—Commander L. A. Beardslee, U.S.N., Chairman, Chief Eng'r D. Smith, U.S.N., W. Sooy Smith, C.E.

Instructions.—To observe and to experiment upon the effects of re-heating, re-rolling, or otherwise re-working; of hammering, as compared with rolling, and of annealing the metals.

(N.) On Steels Produced by Modern Processes.—A. L. Holley, C.E., Chairman, Chief Eng'r D. Smith, U.S.N., W. Sooy Smith, C.E.

Instructions.—To investigate the constitution and characteristics of steels made by the Bessemer, open hearth, and other modern methods.

(O.) On Steels for Tools.—Chief Eng'r D. Smith, U.S.N., Chairman, Commander L. A. Beardslee, U.S.N., W. Sooy Smith, C.E.

Instructions.—To determine the constitution and characteristics, and the special adaptations of steels used for tools.

"The above named Committees of this Board are appointed to conduct the several investigations, and the special researches assigned them in the interval during which the regular work of the Board is delayed by the preparation of the necessary testing machinery, and during such periods of leisure as may afterwards occur.

"These investigations are expected to be made with critical and scientific accuracy, and will, therefore, consist in the minute analysis

of a somewhat limited number of specimens and the precise determination of mechanical and physical properties, with a view to the detection and enunciation of the laws connecting them with the phenomena of resistance to flexure, distortion and rupture.

"The Board will be prepared to enter upon a more general investigation, testing such specimens as may be forwarded to the President of the Board, or such as it may be determined to purchase in open market, immediately upon the completion of the apparatus ordered, at which time circulars will be published giving detailed instructions relative to the preparation of specimens for test, and stating minutely the information which will be demanded previous to their acceptance."

The Board has advertised for suitable testing machines, and other apparatus for the more extended investigations. Meanwhile, several of the above Committees have issued circulars concerning the special subjects they have in charge. Committee A says in its circular:—

"The Board has assumed, as a part of its work, the investigation of the methods and effects of ABRASION AND WEAR of metals in engineering and mechanical operations.

"This Committee is instructed to take up this subject and to report such valuable data and statistics, and such information as it may acquire by experiment or from other observers, in such form that it may be readily collated and made useful to the Government, the public, and the engineering profession.

"The Committee would be pleased to receive from any reliable source precise data and such information as may enable the Secretary to compile, in as concise and exact form as possible, a statement of the mode of deformation, the rapidity of abrasion, and the laws governing wear in any important typical or exceptional cases.

"The executive officers of all lines of railway may render valuable aid by furnishing statements of the wear of rails per ton of transportation specifying with care the original weight, the make, and the character of the rail, the total amount of transportation, the length of time occupied, and stating whether the rail finally broke or was removed. Specimens of rails remarkable either for endurance or for a lack of this quality, if sent to the Committee, will be of use in assisting in the determination of the chemical and other properties which most affect the value of the material under the stated conditions of use.

"Similar statistics and information in regard to the wear of wheels, axles and other parts of rolling stock and machinery will be equally valuable.

"Engineers having in any instance noted and accurately recorded such data, are requested to transmit to this committee copies of their memoranda.

"The wear of journals under heavy loads, or at high velocities, as well as under ordinary conditions, is an important branch of this subject. When possible, it is desired that the dimensions of the journal, the maximum, the minimum and the mean weight sustained, and the velocity of rubbing or number of revolutions per minute should be given. The nature of the lubricant is an essential element, and its composition should be stated, the method and frequency of application and the quantity used should be given. When known, or readily ascertained, the coefficient of friction should be given. It should also be noted whether heating occurs, and under what circumstances of pressure and velocity of rubbing surfaces.

"Peculiar instances of the behavior, or unusual expedients in the management of bearings, if described accurately and concisely, will be accepted, with thanks.

"The wear of tools, under the various conditions of workshop practice, is another subject of investigation.

"Weighing the tools carefully before and after use, and weighing the amount of metal removed will, perhaps, be found the most accurate method of determining the rate of abrasion. The area of surface finished, and the area of the surface cut by the tool should be accurately ascertained and stated.

"The description of the tools, its shape, method of operation, the kind of metal used in the tool, the temper adopted, the character of the metal cut by it, the velocity of the tool, and where peculiarities of behavior were noted, a careful statement of them should be given. This information will still be more valuable if the tool itself and specimens of the chips produced by it are furnished.

"The power required to drive the tool can sometimes be readily determined, and such information is of great value.

"The recent investigations of M. Tresca—*Memoir Sur le Rabotage des Metaux*, etc.—is an excellent example of such research.

"For all information which may properly fall within the limits of their investigation, this committee will return suitable acknowledgment.

"R. H. THURSTON,

"*Chairman.*"

We have also received a circular from the committee marked "J," in which it is stated that the committee "has been instructed, during such time as may be found available pending the construction of the apparatus ordered by the Board for use in general work, and during such intervals as may subsequently be properly appropriated to such purpose, to investigate the mechanical, physical and chemical properties of the alloys of the useful metals, and to determine, if possible, their interdependence and the laws governing the phenomena of combination and of their resistance to stress.

"The Committee desire to obtain records of all experiments which have hitherto been made in this direction, and to secure such exact information as may assist further researches. It is desirable that such records should embody a statement of the precise chemical constitution of each alloy examined, as obtained both by synthesis and subsequent analysis. Its specific gravity, specific heat, conductivity, its combining number, and the relation of its chemical constitution to the series of similar compounds produced by alloying the elements in the proportions of chemical equivalents, should be stated whenever possible. A few thoroughly well studied examples will be of more service than a large number of isolated determinations of single facts.

"It is further desired that the ultimate strength, the elastic limit, the modulus of elasticity, the ductility, resilience, homogeneousness, hardness and other mechanical properties of the specimen be ascertained and accurately stated.

"Where only a part of this work can be done by the investigator, this Committee is prepared to assume charge of the remaining portion of the research, when the alloy can be furnished in proper quantity and form.

"References to published accounts of similar works and monographs on any branch of the subject will be thankfully accepted. Special researches made for this Committee will be received with appropriate acknowledgments.

"The DEPARTMENTS OF PHYSICS and of CHEMISTRY in the various colleges and universities will probably be able to render valuable aid, and their co-operation is earnestly requested.

"The SCHOOLS OF ENGINEERING are in a position to assist this Committee very effectively and their contributions will be thankfully accepted.

"Suitable blanks upon which to record the data offered, will be furnished upon application.

"Specimens of alloys for test by the Committee must be accompanied by a statement upon these blanks of their precise constitution, and such information as it is possible to give, with an account of such peculiarities as are known to distinguish the alloy, and of the special object which it is supposed may be attained by the investigation.

"Where possible, it is required that one or more specimens shall be furnished of each of the specified kinds, and of precisely the form and dimensions, which will be given on application.

"R. H. THURSTON,

"*Chairman.*"

We cannot too heartily endorse the enlightened action of Congress in appointing this Commission, nor that of the President in his most judicious selection of its members. There is every reason to expect from this Board the most full and complete investigation of the sub-

jects which come under its charge, which has ever been made in the history of engineering. We earnestly hope that a broad and patriotic liberality rather than a narrow selfishness will be the motive enlisting the cordial co-operation of all of our metallurgists and manufacturers who can in any way aid in developing results so valuable in themselves and so important to the country at large.

Centennial Exhibition.—The progress on the Centennial Buildings and Grounds, since our last issue, has been very marked and quite satisfactory to the building committee and to the commission, and the advanced stage of the preparations generally, as compared with those for the late European International Exhibition, has been very favorably commented on by several distinguished foreigners, who have had large opportunities for such comparison.

The Main Exhibition Building, of which we give illustrations is in the form of a parallelogram, extending east and west 1,880 feet in length, and north and south 464 feet in width. The larger portion of the structure is one story in height, and shows the main cornice upon the outside at 45 feet above the ground, the interior height being 70 feet. At the centre of the longer sides are projections 416 feet in length, and in the centre of the shorter sides or ends of the building are projections 216 feet in length. In these projections, in the centre of the four sides, are located the main entrances, which are provided with arcades upon the ground floor, and central façades extending to the height of 90 feet.

The East Entrance will form the principal approach for carriages, visitors being allowed to alight at the doors of the building under cover of the arcade. The South Entrance will be the principal approach from street cars, the ticket offices being located upon the line of Elm Avenue, with covered ways provided for entrance into the building itself. The Main Portal on the north side communicates directly with the Art Gallery, and the Main Portal on the west side gives the main passage way to the Machinery and Agricultural Halls.

Upon the corners of the building there are four towers, 75 feet in height, and between the towers and the central projections or entrances, there is a lower roof introduced showing a cornice at 24 feet above the ground. In order to obtain a central feature for the building as a whole, the roof over the central part, for 184 feet square, has been raised above the surrounding portion, and four towers, 48 feet

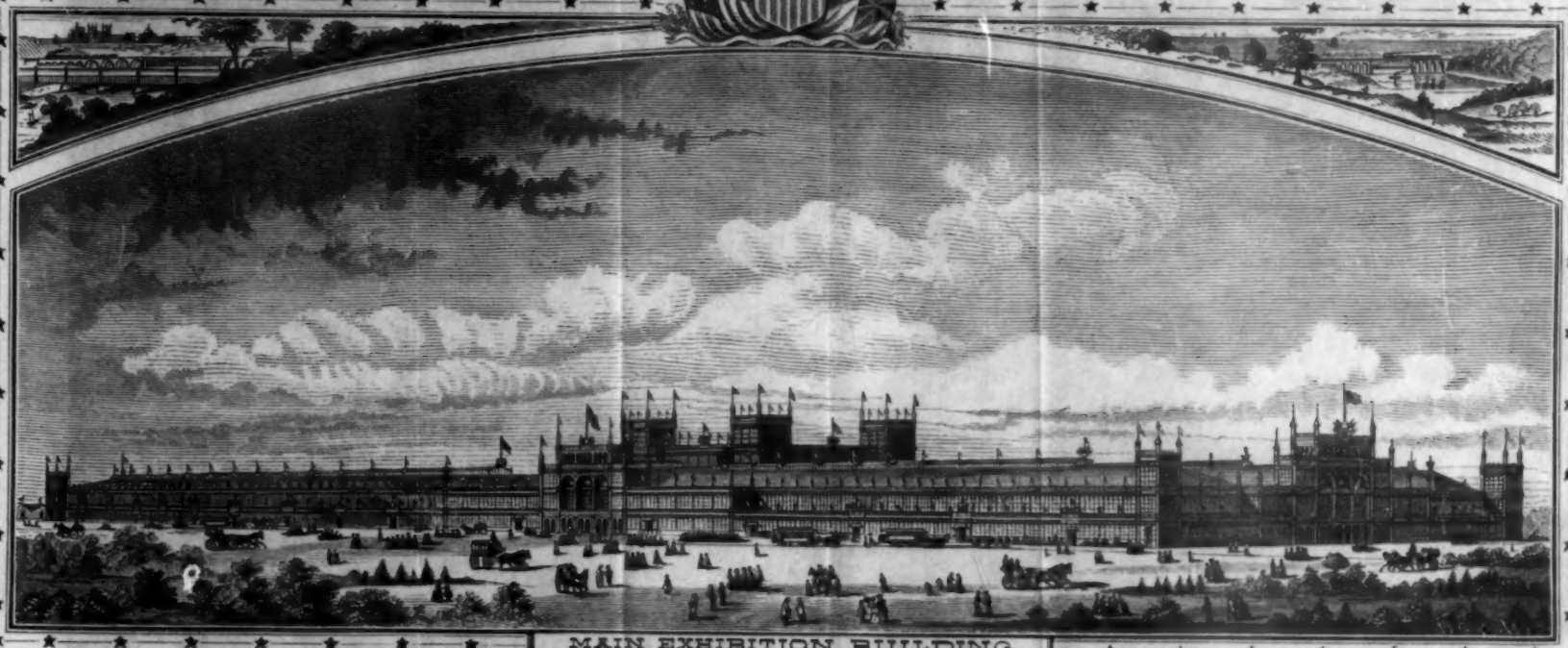
Bird's-eye View of the Centennial Buildings, Fairmount Park, Philadelphia.

Entered according to Act of Congress in the year 1875, by LONGACRE & CO., in the Office of the Librarian of Congress at Washington, D. C.

Birds-eye View of the Centennial Buildings, Fairmount Park, Philadelphia.

PHILADELPHIA U. S. AMERICA

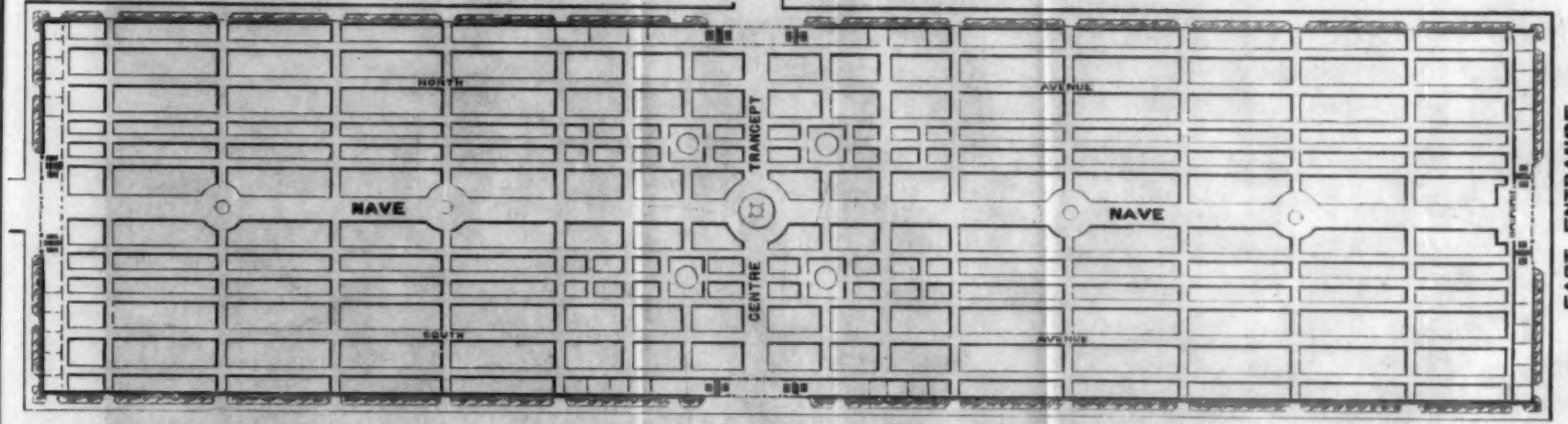
MAY 10TH TO NOVEMBER 10TH 1876.



MAIN EXHIBITION BUILDING.

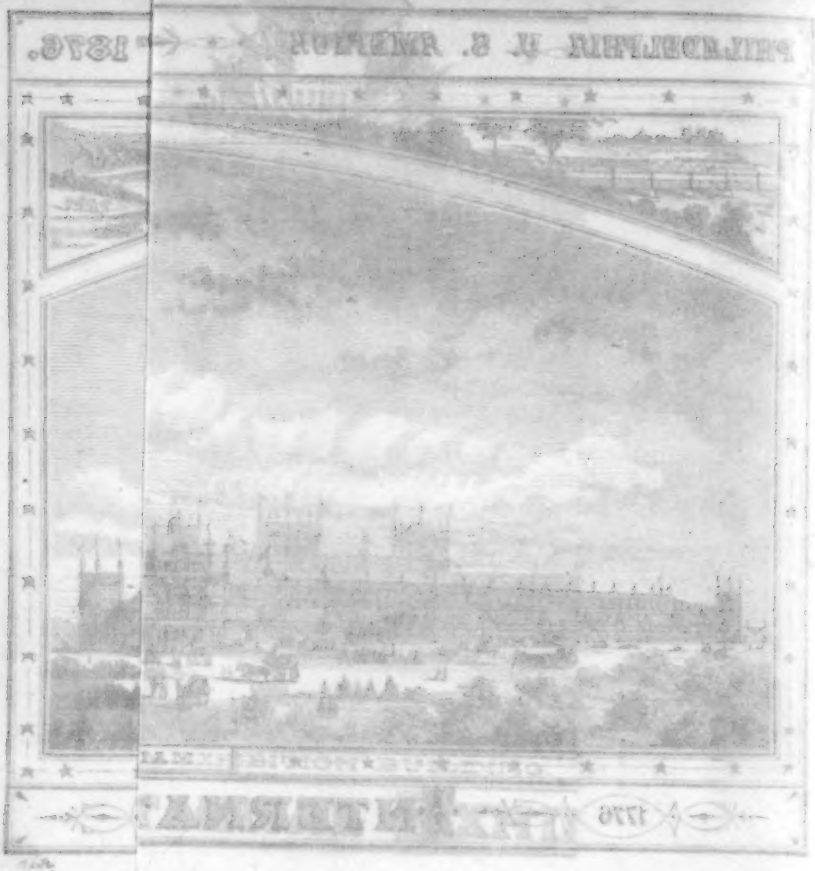
1776 INTERNATIONAL EXHIBITION. 1876

GROUND PLAN.



SOUTH ENTRANCE

ELM AVENUE



LEGEND. PLAN

NAVE

EAST ENTRANCE

SOUTH ENTRANCE

AVENUE

square, rising to 120 feet in height, have been introduced at the corners of the elevated roof.

The areas covered are as follows:

Ground Floor, ...	872,320 square feet.	20·02 acres
Upper Floors in projections, . . .	37,344 " "	·85 "
" " in towers, . . .	26,344 " "	·60 "
	936,008	21·47

The general arrangement of the ground plan shows a central avenue or nave 120 feet in width, and extending 1,832 feet in length. This is the longest avenue of that width ever introduced into an Exhibition Building. On either side of this nave there is an avenue 100 feet by 1,832 feet in length. Between the nave and side avenues are aisles 48 feet wide, and on the outer sides of the building smaller aisles 24 feet in width. In order to break the great length of the roof lines, three cross avenues or transepts have been introduced of the same widths and the same relative positions to each other as the nave and avenues running lengthwise, viz; a central transept 120 feet in width by 416 feet in length, with one on either side of 100 feet by 416 feet, and aisles between of 48 feet. The intersections of these avenues and transepts in the central portion of the building result in dividing the ground floor into nine open spaces free from supporting columns, and covering in the aggregate an area of 416 feet square. Four of these spaces are 100 feet square, four 100 feet by 120 feet, and the central space or pavilion 120 feet square, The intersections of the 48 feet aisles produce four interior courts 48 feet square, one at each corner of the central space.

The main promenades through the nave and central transept, are each 30 feet in width, and those through the centre of the side avenues and transepts 15 feet each. All other walks are 10 feet wide, and lead at either end to exit doors.

The foundations consist of piers of masonry. The superstructure is composed of wrought iron columns which support wrought iron roof trusses. These columns are composed of rolled channel bars with plates riveted to the flanges. Lengthwise of the building the columns are spaced at the uniform distance apart of 24 feet. In the entire structure there are 672 columns, the shortest being 23 feet and the longest 125 feet in length. Their aggregate weight is 2,200,000 pounds. The roof trusses are similar in form to those in general use for Depots and Warehouses, and consist of straight rafters with struts

and tie-bars. The aggregate weight of iron in the roof trusses and girders is 5,000,000 pounds. This building being a temporary construction the columns and trusses are so designed that they may be easily taken down and erected again at another site. The sides of the building for the height of seven feet from the ground are finished with brickwork in pannels between the columns. Above the seven feet, with glazed sash. Portions of the sash are movable for ventilation. The roof covering is of tin upon sheathing boards. The ground flooring is of plank upon sills resting upon the ground, with no open space underneath. All the corners and angles of the building upon the exterior are accentuated by galvanized iron octagonal turrets which extend the full height of the building from the ground level to above the roof. These turrets at the corners of the towers are surmounted with flag staffs, at other places with the national eagle. The national standard with appropriate emblems is placed over the centre of each of the four main entrances. Over each of the side entrances is placed a trophy showing the national colors of the country occupying that part of the building, At the vestibules forming part of the four main entrances variegated brick and tile have been introduced. The building stands nearly due east and west and is lighted almost entirely by side light from the north and south sides. Louvre ventilators are introduced over the central nave and each of the avenues. Skylights are introduced over the central aisles. Small balconies, or galleries of observation, have been provided in the four central towers of the building at the heights of the different stories. These will form attractive places from which excellent views of the whole interior may be obtained. A complete system of water supply with ample provision of fire cocks, etc., is provided for protection against fire, and for sanitary purposes.

Offices for Foreign Commissions are placed along the sides of the building in the side aisles, in close proximity to the products exhibited. As many of the 24 feet spaces being partitioned off for that purpose as may be required. Offices for the administration may be placed at the ends of the building and on the second floor.

The form of the building is such that all exhibitors will have an equally fair opportunity to exhibit their goods to advantage. There is comparatively little choice of location necessary, as the light is uniformly distributed and each of the spaces devoted to products is located upon one of the main thoroughfares.

The erection of the main exhibition building is progressing very

satisfactorily, six or eight sections per week being added, at which rate the entire framework should be completed in August.

The setting of the granite on the south and east fronts of the Art Building is nearly completed, and on the other portions being well along. The roof is being placed on the eastern half, and the scaffolding for the erection of the dome is in place.

All the framework of that portion of Machinery Hall from its eastern end to the transept (nearly half) is up, and considerable of it is under roof, and is expected to be floored and so far finished that it will be used for the celebration of the 4th of July. Meanwhile the western half of the building is being erected with the same energy that has been so apparent since its commencement.

The Horticultural Hall has risen to the coping of the masonry, and is now receiving the iron framework of the superstructure. One of the Administration Offices, 100 by 80 feet, is so far completed that a portion is now occupied.

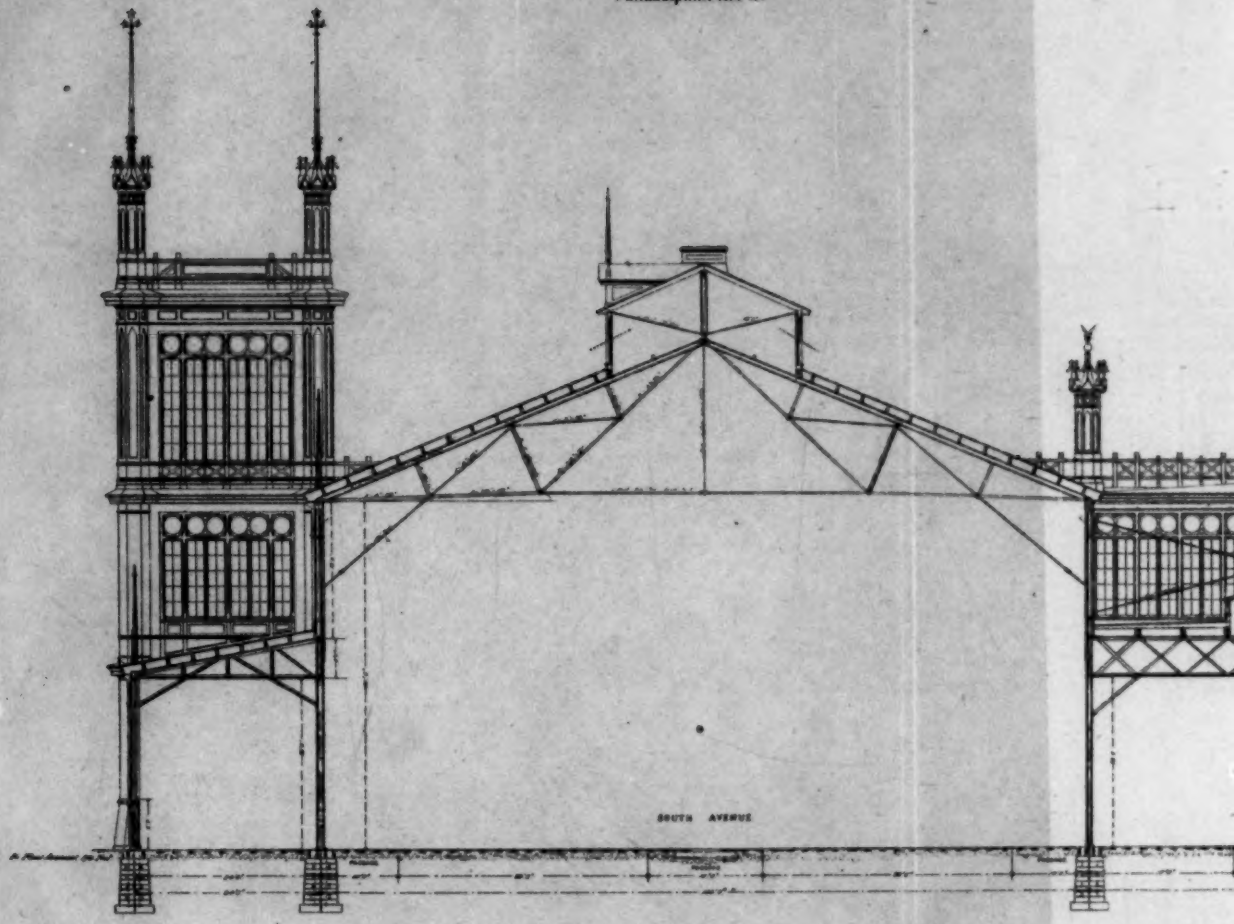
Ground will be broken for the Agricultural Building on the 5th of July next, and the arrangements for its erection are of such a character, as to insure its completion in ample time.

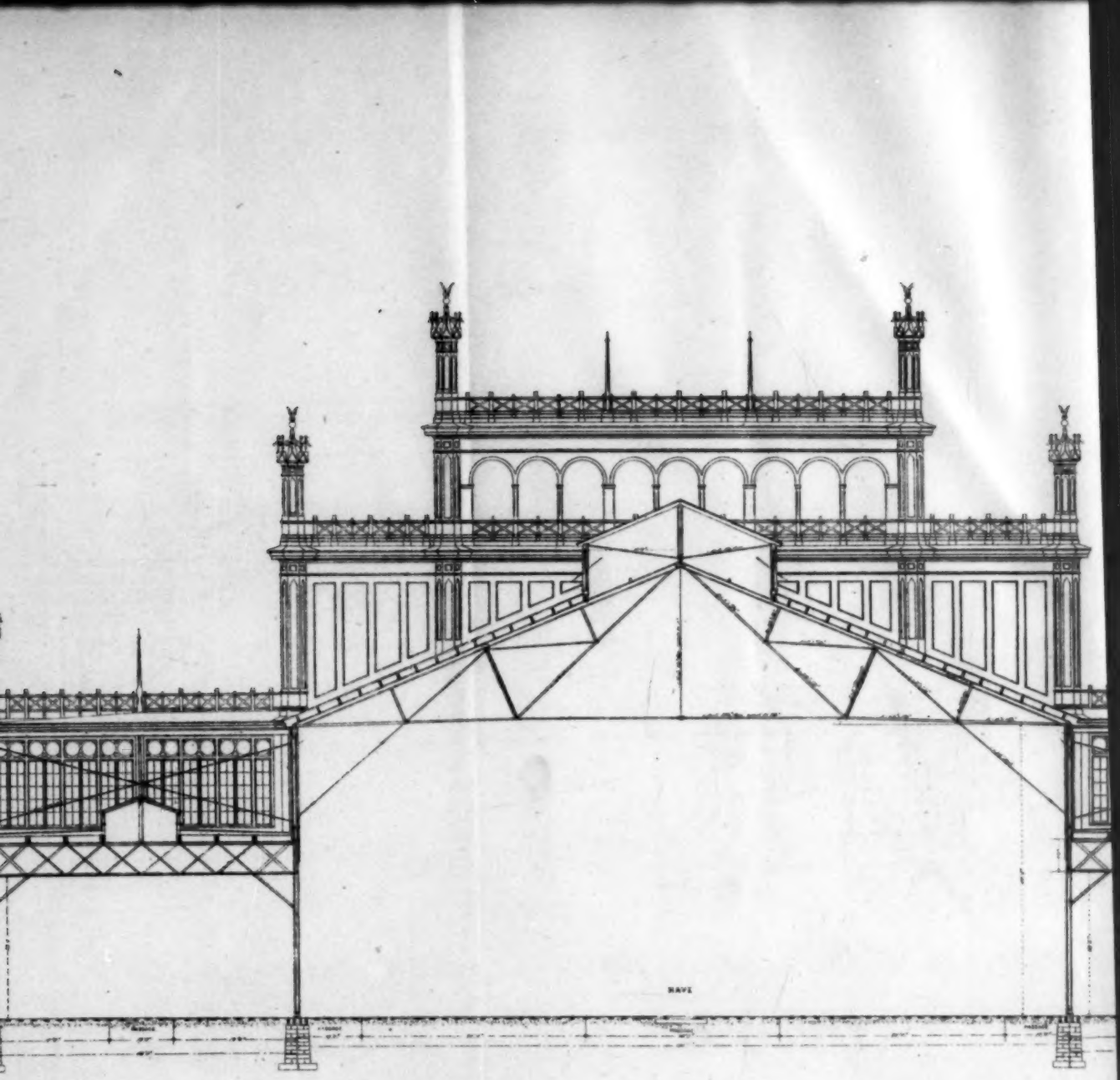
The designs for the Bridge across Landsdowne Valley are completed and the contract for its erection is executed. This bridge, which was originally intended to be a temporary one, it is now proposed to make a permanent structure. It will be 80 feet wide, and the line of the enclosure of the grounds will divide its width, leaving 50 feet outside for the park drive and 30 feet on the inside as a means of communication between the Art Building and Horticultural Hall.

A contract has been entered into with Mr. H. R. Worthington, of New York, for the erection of a compound duplex pumping engine of five to six millions gallons capacity, to supply the Exhibition with water. This will be located on the bank of the Schuylkill, on the north of Landsdowne Creek, and the water will be conducted thence up the valley to the system of distributing pipes in the various buildings and grounds.

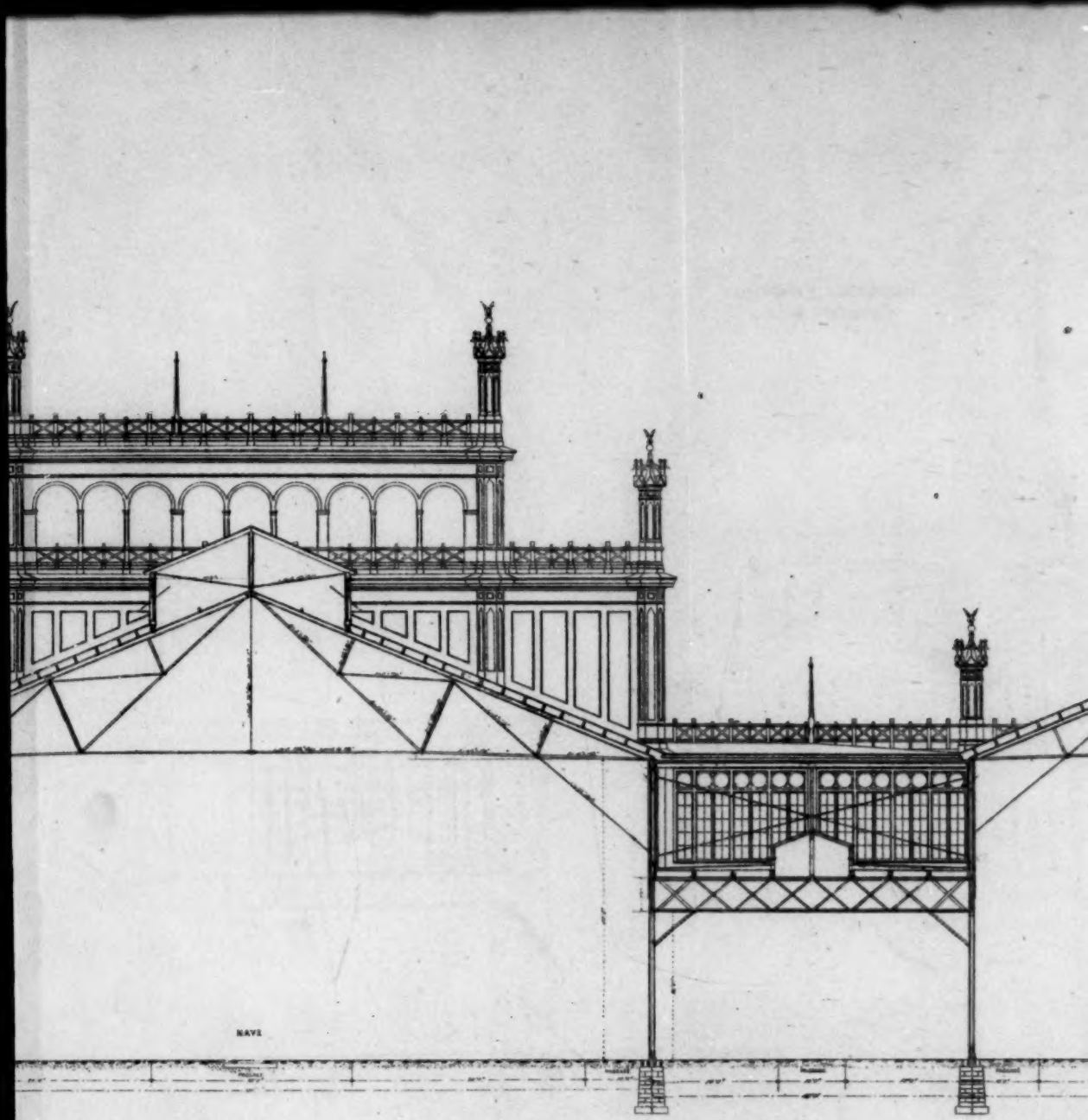
The correspondence with foreign governments and commissions shows that active and extensive preparations are being made by nearly all of them for participating in our national celebration, and while there is no doubt that our own people have the matter very much at heart, it is well to consider whether we are sufficiently alive to the importance of beginning our preparations at once and of making early application for space. K.

International Exhibition.
Philadelphia. 1876.



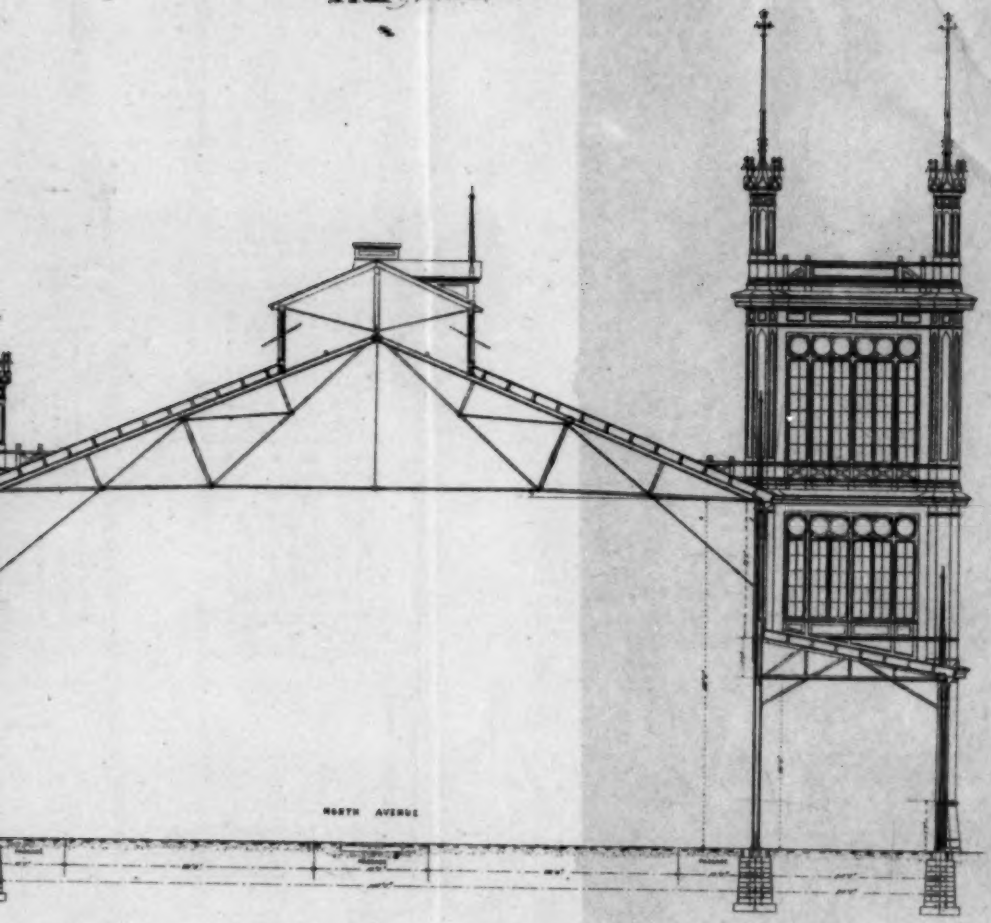


№ 7.
Section through Wings.



No 7.
Section through Wings.

Main Exhibition Building.



Merriman's Water-proof Life Saving Dress has attracted much attention for a year past and has been subjected to very severe tests, which have fully confirmed the high opinion expressed in its favor last summer.

Its good qualities were fully developed by Capt. Boyton in his two trips across the English Channel, quite recently; and at the meeting of the Institute in April, a duplicate of the one used by him was exhibited.

The dress is composed of two principal parts: the upper portion consists of the shirt or jacket, a head piece, sleeves and gloves, all in one piece, and made of rubber-cloth or other water-proof material. The lower portion is composed of the pantaloons and boots in one piece of similar material. The front of the head piece, corresponding with the face of the wearer, is made highly elastic, and has an aperture of suitable size to expose the eyes, nose and mouth. The top, back and sides of the head piece are made double, forming a cavity for the purpose of admitting of expansion by inflation. The effect of this inflation is not only the support of the head when it rests upon the surface of the water, but it draws the elastic edges of the aperture tight around the face, preventing the ingress of water to the interior of the dress.

The back and front of the shirt are also double, the cavity in the back extending upward over the back of the neck to the head. The pantaloons are also double from the waist to the knees, forming cavities front and back for inflation.

All these cavities are provided with flexible tubes, long enough to reach the mouth of the wearer and have proper valves and stop-cocks. By means of these tubes the several parts of the dress may be inflated to any desired degree. At the upper edge of the pantaloons is fastened a rigid hoop, over which is stretched the lower edge of the shirt, and secured water-tight by means of a waist belt drawn firmly around all.

By dividing the dress in two parts, which can be readily joined in a water-tight manner, it can be put on and secured by the wearer in a very short time, and inflated without aid from others.

A great advantage of this dress, besides its floating power, is that the air cavities surrounding the vital portions of the body, protect it from becoming chilled by long exposure in the water. K.

Chemical Composition of Metaline.—We find a note upon this new dry lubricant in *Dingler's Polytechnisches Journal*, written by Vogdan Hoff. During his residence in London, he had considerable experience with it, and with the company manufacturing it. In order to reduce the friction to a minimum, the greatest care is necessary in working the surfaces which are to come in contact, so as to run perfectly true and to have a high polish. In the bearing holes are bored in series, two or three centimeters distant from each other, and three millimeters deep. These are then filled with metaline, which thus constitutes the sole lubricating material. The substance itself is a graphite-like mass only a little harder than lead. It does not melt on being heated, but evolves a tar-like odor. On cooling, it returns to its original consistence. Under the microscope, some of its constituents may be detected, namely, scales of graphite, metallic particles, and amorphous white grains. A specimen furnished by the metaline company, on being subjected to analysis, afforded the following composition :

Paraffin,	4·98.
Carbon,	18·89.
Silica,	6·44.
Lime,	3·96.
Magnesia,	1·99.
Ferric Oxide,	3·94.
Alumina,	2·53.
Lead,	32·40.
Zinc,	20·07.
Tin,	1·55.
Copper,	2·75.
Moisture,	0·51.
	100·01.

Tracing Paper.—M. C. Puscher has lately invented a very simple method of making and unmaking tracing paper, which promises to be of great service. The drawing paper to be made transparent is well moistened with a sponge wet with a solution of castor oil in two or three times its volume of absolute alcohol, according to the thickness of the paper. After a few minutes the alcohol evapo-

rates and leaves the paper ready for use. The drawing may now be made upon it either in crayon or in India ink. After this the paper is restored to its original opacity by immersing it for a given length of time into absolute alcohol, which dissolves and removes the oil. The alcohol so used serves for making a new solution.

Bibliographical Notices.

THE MICROSCOPE AND ITS REVELATIONS. By WILLIAM B. CARPENTER, M.D., L.L.D., etc. Fifth edition; illustrated by twenty-five plates and four hundred and forty-nine woodcuts. Small 8vo., pp. xxxii, 848. Philadelphia, 1875. (Lindsay & Blakiston.) The present treatise on the microscope has been long known as perhaps the best book in English upon the general subject. The high position of its author among physiologists, and his extensive acquaintance with the microscope in connection with his special studies, makes him abundantly competent in this direction. In the edition before us, the whole of the matter is stated to have been carefully revised. Many new forms of microscope and of microscopical appliances are now described for the first time, and some of the more important results of microscopical investigation have been introduced. For the American reader, however, it would have been desirable to mention some of the noteworthy stands and objectives made in this country, and to have given more space to the microscopic work done here. Mr. Tolles is the only manufacturer mentioned, and he only incidentally. Dr. Woodward's excellent work, especially in photography, and Dr. Wormley's in micro-chemistry are referred to, though not *in extenso*. Without raising the question here whether an entirely new book is not preferable to a new edition of quite an old one, we may still say that the beginner in microscopy will find this book of Dr. Carpenter's very useful for consultation; and that the advanced microscopist will find its well arranged pages of great service for ready reference. Of course, as in all cases of special study, monographs on the particular subject under investigation, can alone be expected to give minute microscopic details. The book before us is a fac-simile of the English edition, having been printed (and we suppose bound) on the other side of the ocean, for the American publishers, and with their imprint. The plates and woodcuts are excellent, and the general typography and binding are very creditable.

Franklin Institute.

HALL OF THE INSTITUTE, April 21st, 1875.

The stated meeting was called to order at 8 o'clock, P.M., the President, Dr. Robt. E. Rogers in the chair.

There were 92 members present.

The minutes of the stated meeting, held March 17th, were read and approved.

The Actuary presented the minutes of the Board of Managers, and stated that at the meeting held on the 14th inst., the following donations to the Library were received:

Geological Survey of Canada. Report of Progress for 1873–4. From A. R. C. Selwyn, F. R. S., &c.

Report of the Commissioner of Education for the year 1873. From the Commissioner. Washington.

Report of the Proceedings of the Conference on Maritime Meteorology, held in London, 1874. Protocols and Appendices. From the Meteorological Committee. London.

Fifth Annual Report of the Board of Commissioners of Public Charities of the State of Pennsylvania, 1874. From the Board of Public Charities.

The Secretary reported that the Board at its last meeting, considered the plans for the alteration of the Institute Building, submitted by the committee appointed for that purpose, and approved of that portion relating to the second floor, which contemplates removing one of the stair-cases and a portion of the partition between the Library Room and the Hall, thus utilizing about three-fifths of the latter for the use of the Library. The plans were then referred back to the committee for perfecting in detail, and to have embodied in them arrangements for heating and ventilation.

The Secretary presented the "Sansom" wheel jack, the invention of H. E. Nittinger, a convenient and compact instrument for raising and holding the axles of wagons and other vehicles, while the wheels are cleaned or removed. Also a specimen of an improved dioptric, or water light, the invention of M. C. Meigs, Quartermaster General U. S. A., for the use of students, mechanics, artists, and others who need a strong light, which shall at the same time be steady and soft.

The Secretary presented a statement showing an increasing demand for Engineering Instruments of Philadelphia make; Messrs. Heller & Brightly having recently received a large number of foreign and domestic orders which have heretofore been given to European manufacturers.

As a matter of interest connected with the coming Centennial, the Secretary projected on the screen a plan and elevation of a hotel to be 669 feet long by 204 feet wide, occupying the square of ground bounded by 39th and 40th, Poplar and Sylvan Streets. It is proposed to so construct the building that it may be easily converted into dwellings, such as are likely to be in demand in that section of the city after the exhibition is over.

The Secretary then presented a large number of views showing considerable advancement on the Centennial Buildings, also a plan of the situation of the different buildings, and other improvements in the Centennial grounds.

Mr. J. E. Mitchell offered the following amendment to the By-Laws:

Resolved, That Section 7 of Article 2 of the By-Laws be repealed.

In response to an inquiry, the chair made some further explanation of the proposed alterations to the building, and some discussion followed, participated in by Messrs. Close, Hoover, Lippman and Orr.

Mr. J. J. Weaver offered the following amendment to the By-Laws.

Article 5, Section 1 of By-Laws be amended by adding to the second sentence the following: "And, provided further, that no member of the Board of Managers shall be eligible for re-election as a Manager for the period of two years after his term of office has expired."

Article XVI, of By-Laws, be amended, by striking out the last sentence, and substituting the following: "In all cases, notice of proposed amendments shall be given in connection with the notice of meeting at which said amendment is to be acted upon, by publication daily in three or more newspapers, published in the city of Philadelphia, for at least three consecutive days immediately preceding the time of said meeting." These amendments were seconded by Mr. Chabot.

Mr. Close moved to postpone the advertising of all the proposed amendments for one month, which was carried.

On motion the meeting then adjourned.

J. B. KNIGHT, *Secretary.*

Civil and Mechanical Engineering.

ON THE THEORY OF THE TENSION OF BELTS.

By Prof. L. G. Franck, of the University of Pennsylvania.

A few gentlemen practically engaged in mechanical engineering, who, as they state, have sufficient knowledge to follow a mathematical demonstration, requested me to advance a theory on the tension of belts on pulleys, for comparison with their own practical experience, and they further express the desire to have the theory published in one of the scientific periodicals.

Complying with their wishes, I have to make a few preliminary remarks, upon which the subsequent theory is based.

The friction* of the belt on the circumference of the driving pulley is, in my opinion, the force that drives the belt with the same circumferential velocity with which the pulley moves.

But as this is contrary to the views of many writers on mechanics, and as it is laid down in standard works that friction is but a negative force—that, in other words, friction can never be the source of motion—therefore it appears to me necessary to establish argumentatively the view above expressed.

If it were true that friction never can become a positive force, the uppermost doctrine in mechanics, namely, that action and re-action are equal to each other, would be radically destroyed. There are quite a number of examples which clearly show that friction is the source of motion. For if the motion of a body upon a support is to some degree resisted by friction, this same friction reacts upon the support equally, and will either move it or will have a tendency to do it. This is illustrated by the friction wheels, friction clutches, the jump-

* Some writers call this force adhesion; but as it will be shown in the sequel that this force is independent of the area or surface, it cannot properly be called adhesion, which we know is dependent on area.

ng back of a wedge-shaped key, and also by air passing over a surface of water, in consequence of which particles of the water are put in motion.

I shall now proceed to derive a few formulæ, and will illustrate them by numerical examples. In order not to involve too much mathematics, I shall set out with the well-known formula derived almost in every treatise on mechanics:

$$P = \left(1 + 2f \sin \frac{\alpha}{2}\right)^n Q. \qquad (1)$$

where P denotes the force required to start the weight Q; f, the coefficient of friction; α, the angle which two planes form; and n, the number of faces over which the belt passes. (Fig. 1.)

Fig. 1.

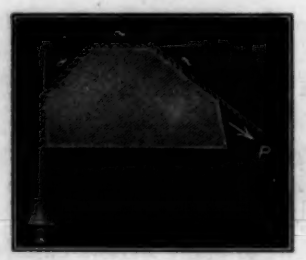


Fig. 2.

Now, fitting the above formula for a cylindrical surface—regarding the pulleys as cylinders—we must put α equal to the angle which two consecutive elements of a circle form. Since the number of elements is very great, the angle $\frac{\alpha}{n}$ is very small, and since the sine of a very small angle approximates its arc, we can put: (Fig. 2.)

$$P = \left(1 + 2f\frac{\alpha}{2n}\right)^n Q.$$

Raising this expression to the nth power, by means of the binomial theorem, and rejecting all terms after the second, as these quantities are not assignable, we obtain:

$$P = (1 + f\alpha)Q. \qquad (2)$$

where P and α are variable quantities, α denoting now any small portion of the circular arc AB, around which the belt stretches. If we

divide again the arc AB into elements and calculate the force P for the elements in succession, and add all these forces, we finally get the amount P to start the force or weight Q. This is shortest performed by calculus, as the subsequent derivation will show. From above we have:

$$P=Q+f\alpha Q; \text{ or } P-Q=f\alpha Q.$$

Now for the first element, near the origin A. Q is almost equal to P, wherefore we can put $P-Q=dP$,* and P instead of Q; we shall find then, putting for α its element $d\alpha$:

$$\frac{dP}{P}=fd\alpha.$$

Integrating between the limits A and B, we find:

$$\text{Log } P=f\alpha+C.$$

To determine the constant C, we have in the beginning $P=Q$ and $\alpha=0$. Hence, $\log Q=0+C$. Therefore the whole expression becomes: $\text{Log } P-\log Q=\alpha f$, which gives:

$$\text{Log}\frac{P}{Q}=\alpha f, \text{ and } P=Qe^{\alpha f}. \qquad (3)$$

where e indicates the base of the Naperian system of logarithms = 2·718. We infer then from the above equation that if a weight Q attached to a flexible band (Fig. 2) is to be dragged around a fixed cylinder:

1. The force P is independent of the radius of the cylinder or pulley. That is to say, the amount of P remains the same whether the band, belt, or cord is wrapped say once about a cylinder whose diameter is one or ten feet.

2. The force P does not depend upon the width of the belt, as no algebraic symbol appears in equation (3) which expresses the width of the belt.

3. The force P depends on the pressure or tightening, (Q.)

4. The force P depends on the arc of contact between the belt and the smaller pulley, (α.) (Fig. 2.)

5. The force P depends on the coefficient of friction between the belt and surface of the pulley, (f.)

The value e remains constant under all circumstances. Now if we pass from the fixed pulley to two movable pulleys, turning around

* Differential of P.

their axes A and B, by means of a belt b a, a_1 b_1, that is put in motion by the driving pulley B (Fig. 3), transmitting its motion to the fol-

Fig. 3.

lower A, we have for the moment of resistance offered by the follower A, the product of the circumferential force and its lever-arm R, that is:

$$M = SR. \qquad S = \frac{M}{R}. \qquad (4)$$

In order that the belt shall not slip, the friction F on B must be equal to the force S (for equilibrium).

Now as the force P (tension of belt b a) has to overcome both the friction and the resistance (weight Q), the friction itself must therefore be equal to $F = S = P - Q$.

Hence if we subtract Q from the second member of equation (3) we obtain:

$$F = Q(e^{\alpha f} - 1). \qquad (5)$$

The arc α must be taken on the smaller pulley, as this gives the least value; and as F is independent of the radius, the arc is in all cases to be calculated for radius = 1.

While for pulleys with an open belt the angle is least at the smaller pulley (Fig. 3), the angle is the same no matter what size the pulleys have when the two branches of the belt cross each other (Fig. 4.)

Fig. 4.

Now to derive the expressions for the tension of the advancing belt a b, and the retiring belt $b_1 a_1$, (Fig. 3), we find when we put for $F = P - Q$, $P - Q = Q(e^{af} - 1)$, and as $Q = P - S$ from above, the expressions:

$$P = \frac{e^{af}}{e^{af} - 1} S, \quad \text{and} \quad Q = \frac{S}{e^{af} - 1}. \qquad (6)$$

It appears then, from the inspection of the two last formulæ, that the greater we make the product of *af*, the less the tension P becomes. This I shall illustrate by two numerical examples.

Example 1. Required the tension of the advancing belt, when the two pulleys are equal in size and the coefficient of friction between leather belts and cast-iron pulleys is taken 0·25 on an average.

Here $a = \pi =$ half circumference $= 3{\cdot}14$. . . . Hence

$$P = \frac{2{\cdot}718^{3.14 \times 0.25}}{2{\cdot}718^{3.14 \times 0.25} - 1} S = \frac{2{\cdot}718^{0.785}}{2{\cdot}718^{0.785} - 1} S = 1{\cdot}84S.$$

Example 2. Required the tension of the advancing belt, when only four-tenths of the circumference of the smaller pulley is covered, f to remain 0·25.

$$P = \frac{e^{af}}{e^{af} - 1} S = \frac{2{\cdot}718^{6.28 \times 0.4 \times 0.25}}{2{\cdot}718^{6.28 \times 0.4 \times 0.25} - 1} S = \frac{2{\cdot}718^{0.628}}{2\,718^{0.628} - 1} S$$

$$P = 2{\cdot}14S \ (7), \quad \text{and} \quad Q = \frac{S}{2{\cdot}718^{0.628} - 1} = 1{\cdot}14S. \qquad (8)$$

These theoretical values show that the advancing belt in the first example will be stretched by 1·84S, and in the second by 2·14S. But as in practical application it is impossible to get the exact value that is furnished by the theory, and as we have not brought into the calculation the stiffness of the belt nor the axle friction, we have to increase somewhat these theoretical values. Following here Reauleaux' advice, we add 0·26S. which will give us in the second example,

$$P = 2{\cdot}4S \ (7), \text{ and } Q = 1{\cdot}4S. \quad (8.)$$

The arithmetical mean of both values $P_o = \frac{2{\cdot}4 + 1{\cdot}4}{2} S = 1{\cdot}9S$, expresses then the amount of tension that should be given to the belt before motion takes place.

For cast-iron pulleys with open leather belts of about three-sixteenths of an inch thickness, the above two formulæ (7) and (8), provided that one of the pulleys is not very small comparatively, may be applied generally.

TO DETERMINE THE WIDTH OF THE BELT.

The tension of the belt is counteracted by the cross-section of the belt, that is $2{\cdot}4S = wtK$, where w denotes the width of the belt, t the thickness, both given in inches, and K the number of pounds which one square inch of belt will fairly resist, found by experiment.

From equation (5) we have $S = \frac{M}{R}$ introduced into the above equation and solved with respect to w, we find $w = \frac{2{\cdot}4M}{tKR}$. (9)

In general M is not directly known, but the number of horse powers the pulley shall transmit is given, and the number of revolutions per minute of the pulley, or the number of feet that the belt travels per minute. From these data we are enabled to express S. Putting formula (9) in the form

$$w = \frac{2{\cdot}4S}{tK}, \qquad (10)$$

the dynamical effect of S for n revolutions in one minute is expressed.

Number of horse powers $= N = \frac{2\pi RSn}{33000}$, from which we get $S = \frac{33000N}{2\pi Rn}$, which when introduced into equation (10) gives $w = \frac{2.4 \times 33000N}{2\pi RntK}$ where w denotes the width of the belt in inches, N the number of horse powers, R the radius in feet, n the number of revolutions, t the thickness of the belt, and K the resistance expressed in pounds which one square inch of belt can fairly counteract. Taking t = 3-16 inches, and for K, after Morin, 275 pounds. K depends on the quality of the leather, and ranges from 275 to 550 pounds per square inch. 275 pounds are recommended, however, by good authorities. Applying the latter we shall find, after reducing

the above numerical values, $w = \frac{250N}{nR}$, (11)

where the numerical value is rounded off to an even number.

Example 1.* A pulley of 1½ feet radius makes 80 revolutions per minute, having to transmit one horse power. What should be the width of the belt?

Here $N = 1$; $n = 80$, and $R = 1\frac{1}{2}$.

Hence $w = \frac{250}{80 \times 3\text{-}2} = \frac{25}{12} = 2\ 1\text{-}12$ inches.

Example 2. A pulley of 3 inches radius makes 900 revolutions per minute, and has to transmit 2 horse powers. What should be the width of the belt?

$N = 2$; $n = 900$; $R = \frac{1}{4}$ ft. $w = \frac{250 \times 2}{900 \times \frac{1}{4}} = 2\ 2\text{-}9$ inches.

Solving equation (11) with respect to N, we find:

$$N = \frac{wnR}{250}. \qquad (12)$$

Giving to w the exceptional width of 6 inches for a single belt, and assuming $n = 100$ revolutions per minute, and further the radius of the pulley $R = 1$ foot, we find the number of horse powers:

$$N = \frac{6 \times 100 \times 1}{250} = \frac{60}{25} = 2{\cdot}4 \text{ horse powers.}$$

The number of horse powers that are obtained is comparatively small, and it indicates that with pulleys and belts we cannot produce a very great effect unless we make the radius of the pulley very great, and apply an exceptionally great speed.

I should mention that the above formulæ refer to pulleys with open belts only, and that it is of no consequence whether the radius and respective number of revolutions are taken from the greater or

* As great nicety is not required in these calculations, the coefficient of friction may be taken in general as 0·25, and the arc covered by the belt as three-tenths of the circumference of the smaller pulley.

smaller pulley, as the numbers of revolutions are in an inverse ratio to the radii of the pulleys. That is,

$$\frac{R}{R_1} = \frac{n_1}{n}. \quad \text{Hence } Rn = R_1 n_1.$$

If the belt is made up of two layers or thicknesses, so that such a belt of the same width as a single one contains the double cross section, we still may apply the upper formula, if we multiply it by $\frac{2}{3}$, owing to the greater stiffness of the belt.

Example. In order to transmit 4 horse powers, we have a pulley 1 ft. 8 in. by 120 revolutions per minute. What should be the width of the belt?

$$N = 4;\ R = 1\tfrac{2}{3} \text{ ft.};\ n = 120.$$

$$w = \frac{2}{3}\frac{250N}{nR} = \frac{2}{3}\frac{250 \times 4}{120 \times 5\text{-}3} = 3\tfrac{1}{3} \text{ inches.}$$

For the single belt we should have received:

$$w = 3\text{-}2 \times 3\tfrac{1}{3} = 5 \text{ inches.}$$

COMPOUND AND NON-COMPOUND ENGINES, STEAM-JACKETS, ETC.

By Charles E. Emery, C. E., New York.

(Continued from Vol. lxix, page 277.)

(4 C.) It should be here observed that in the above comparison of the results of experiments with the steamer Bache and of the revenue steamers, the former shows more inferiority than can be attributed simply to the difference in size, and we are of the opinion that it was due somewhat to the quality of the steam furnished by the boilers. The boiler of the Bache was constructed to give a high evaporation, and the combustion was so slow that the steam in the steam-chimney received practically little heat from the escaping gases. On the revenue steamers, the boilers were made to develop the maximum power for a given space—the tubes were shorter, the draft freer, and the experiments being tried at maximum power, the gases passed through the steam chimney at a higher temperature than on the Bache, so that

the steam was more thoroughly dried. It appears incidentally, then, that a boiler with a less evaporative power than another, may, within certain limits, furnish steam of a better quality, and thereby produce increased economy in the engine. This is not fully demonstrated by these experiments, as both the size of the engines and the proportions of the boilers are different in the two series, but that there is some such compensation appears probable.*

In these experiments, however, the higher evaporation in the boiler of the Bache, more than compensated for the loss of efficiency in the engine, the best results with the compound engine of the Bache and that of the Rush being as follows:

	Bache.		Rush.	
	Table No. 1, Exp. 6.		Table No. 2, Exp. 1.	
Water actually used per I. H. P., per hour.	(line 46)	20·332	(line 53)	15·384
Water actually evaporated per pd. of coal.	(line 53)	9·131	(line 63)	7·649
Coal consumed per I. H. P., per hour.	(line 49)	2·227	(line 57)	2·435

The presentation shows that while there may be an interesting subject (which we shall investigate further), as to the compensation attainable in the engine by utilizing the waste heat of a boiler with low evaporative power, the higher evaporation will probably, as in this case, prove the better practically. Referring to Table 2, Exp. 1, line 70, it will be seen that with an evaporation of ten pounds of water per pound of coal, (a result attainable under the conditions named), one horse-power, would have cost but 1·838 pounds of coal per hour.

5. Economy of Steam as Influenced by the Steam Pressures employed.—The investigations with which we have been associated show invariably that, other things being equal, the higher the steam pressure the greater the economy. The saving, however, decreases rapidly, using ordinary engines, after a pressure of eighty pounds per square inch is reached, so much in fact that it is doubtful if pressures in excess of one hundred pounds would give a sufficient economy of

*It is to be regretted that the quality of the steam was not tested in all the experiments by means of a calorimeter. The writer, previous to the trial of the Bache, developed and put in practice a very simple apparatus for the purpose, but it was thought that there was so much to be done in a limited time, that the solution of the more important problems could only be attempted.

fuel to counter-balance the extra expense in constructing and maintaining the boilers. We have little information as to what can be done at pressures above one hundred pounds, with engines particularly designed for the purpose, and it is probable that a saving of space occupied by the machinery might in some cases warrant the use of very high pressures even with ordinary engines. Within the limits of common practice, the saving by the use of the higher pressures is very important, and some valuable information on the subject may be obtained from the experiments under discussion. We first examine the results due to using different steam pressures in the same cylinder.

(5 A.) With the non-compound engine of the Dexter, we find (Table No. 2, line 76) comparing experiments 3 and 7, which show the minimum cost at the approximate steam pressures respectively of 70 and 40 pounds, that the power at latter pressure cost 20·73 per cent. more than at the former. This is at about the same degree of expansion, and therefore doing less work, with the less pressure. Were it necessary to do the same work, in the same cylinder, as is the case in practice, comparing runs 3 and 9, we find the power would cost 33·24 per cent. more.

(5 B.) Experiments 13 and 17 on the Bache (Table 1), made at the steam pressures of 78 and 31 pounds, respectively, show a cost for the latter 29·6 per cent. greater than for the former.

(5 C.) In the case of the compound engine of the Rush (experiments 1 and 2, Table 2), made with the steam pressures of 69 and 37 pounds, respectively, the cost of the power at latter pressure is 20·18 per cent. greater than in the former.

(5 D.) The results due to working steam of different pressures in engines properly proportioned to give the maximum economy for the pressure used, involves questions discussed in the next title. Referring, however, to the results shown above, (5 A) and (5 B), it may be observed that if the lower pressure of steam is to be used, it can better be done in a cylinder proportioned as above indicated, and such was very nearly the case in the Dallas. Comparing experiments 11 and 3 (Table No. 2), where the power is nearly the same, we find (line 76) that the power in the low pressure engines of the Dallas cost 13·01 per cent. more than in the high pressure condensing engine of the Dexter.

(5 E.) Above are shown, (5 A), (5 B) and (5 C) practical comparisons of the results due to reducing the steam pressure in the same engine, which furnish a basis whereby we may account for the fact that compound engines in practical use show larger relative economies, compared with simple engines, than we have ascertained by experiment. In high pressure condensing engines, the pressure for various reasons is seldom maintained regularly at the point designed. This occurs from two causes, viz., carelessness of the operating engineer and the improper adaptation, by the designing engineer, of the size of the engine to the work it has to do. The latter, when true, as is too often the case, partially excuses the fault of the former, which subject is discussed in the next title. It is also true that no matter for what pressure the engine is designed, if it be intended to be operated with considerable expansion, the engineer soon finds that his engine works smoother with a lower pressure and less expansion, and naturally thinking, as is too often the case, that his duties are sufficiently arduous, lets his pressure fall or partially closes his throttle-valve and lengthens the cut-off for the most trivial excuses, until finally, notwithstanding his education and instructions, he really believes that it is exactly as well to work that way all the time.

The general prejudice against high pressure is in his favor, and it is not uncommon to have somebody on the vessel boast that their engineer can run with less pressure than somebody else, which is accepted as a matter to be proud of instead of being worthy of condemnation. To be sure, the expense account for coal increases somewhat, but it is attributed to the falling off due to continued service. If protestations of owners that something is wrong are repeated, and direct orders given to work more expansively, the result generally proves a failure; sometimes through lack of interest, and numerous complaints about leaky boilers, &c., and at other times trials are made of higher pressures when the engine really has got out of order and no saving can be observed. It is a fact that if the pistons have become leaky, it is as economical to use a lower steam pressure as a high one. The true remedy in such case is to refit the pistons and carry the pressure designed. We have of late, by the use of special arrangements, found no difficulty in keeping pistons continuously tight at any pressure.

(5 F.) With the compound engine, however, there are fewer mechanical difficulties in working high steam, and in most cases it is

TITLE.		Numper of experiments.	Ratio of expansion.	Mean effective pressure.	Cost in water per horse power per hour.		Number of experiments.	Ratio of expans'n	Mean effective pressure.	Cost in water per horse power per hour.
Table 6 A.		Line 1.	Line 7.	Line 25.	Line 46.		Line 1.	Line 7.	Line 25.	Line 45.
Abstract from general table No. 1, U. S. Coast Survey steamer Bache, non-compound engine, approximate steam pressure 80 pounds.	With steam jacket in use on larger cylinder.	14	12.62	23.449	27.113	Without using steam jacket.	11	11 82	21.643	35.075
		15	8.57	27.54	24.088		12	7.62	27.278	29 616
		16	5.11	36.94	23.154		13	5.32	32.328	26.247
Table 6 B.		Line 10.	Line 17.	Line 36.	Line 53.		Line 10.	Line 17.	Line 36.	Line 53.
Abstract from general table No. 2, U.S. Revenue Steamer Dexter, non-compound engine, approximate steam pressure 70 pounds.	.....	3	4.46	34.439	23.857		5	3.49	37.538	23.905
	.....	4	3.67	37.127	24.120		6	2.72	42.028	24.313
Table 6 C.		Line 10.	Line 17.	Line 36.	Line 53.	U. S. Revenue Steamer Dallas, engine non-compound, approximate steam pressure 35 pounds.	Line 10.	Line 17.	Line 36.	Line 53.
Abstract from general table No. 2.	U. S. Revenue steamer Dexter, (engine non-compound) approximate steam pressure 40 lbs.	7	3.34	25.583	28.802		10	5.07	18.522	26.687
		8	2.42	30.665	28.936		11	3.89	21.447	26.96
		9	2.08	33.838	31.786		13	2.94	24.611	28.901
Table 6 D.		Line 1.	Line 7.	Line 25*	Line 46.		Line 1.	Line 7.	Line 25.	Line 46.
Abstract from general table No. 1, U. S. Coast Survey Steamer Bache, compound engine, approximate steam pressure 80 pounds.	With steam jacket in use on larger cylinder.	4	16.85	20.379	25.108	Without using steam jacket.	1	9.146	22.421	23.765
		5	9.19	27.524	20.713		2	6.658	27.599	23.036
		6	6.97	31.843	20.332		3	5.634	29.781	23.210
		7	5.73	33.484	20.365		...	.....	.....	.....
		10	4.24	36.940	21.169		...	.....	.....	.....

* Mean effective pressure referred to larger cylinder.

difficult to keep up the speed with low steam. For instance, examining experiments 1 and 2 with the compound engine of the steamer Rush, it will be seen (Table 2, line 39) that the power at the lower pressure is much less than with the higher (168·6 to 266·5), so the engineer with an engine of proper size, would be obliged to increase the pressure to obtain sufficient power to propel his vessel at the speed designed. The result is that the average pressure carried for compound engines, even by careless engineers, is much higher than in single cylinder engines, and increased economy due to the steam pressure is obtained, independent of that due to the difference in engines, and we may expect to find in practice, as is commonly reported, that a compound engine operates with a saving of 20 to 25 per cent. compared with single engines using the same pressure, and that even more saving may be obtained when the single engine is greatly too large for its work, as hereinafter discussed.

6. The most economical Point of Cut-off for the Pressure employed.—When it is desired to obtain a given power, using steam of a given pressure, fixing the point of cut-off fixes also the mean pressure in the cylinder, and for a given speed of revolution, the size also of the cylinder required. Our experimental researches show that the most economical grade of expansion varies for every steam pressure, and is influenced somewhat by other conditions.

The preceding tables have been condensed from the general tables, and show the mean pressures and costs of the power at different degrees of expansion for the engines of the several steamers.

Referring to Table 6 A, it will be seen that, with the engine of the Bache, operated non-compound, using an approximate steam pressure of 80 pounds, expanded 5·11 to 12·62 times, the higher grades of expansion were attended with positive loss, and by reference to Table 6 B it will be seen that, with the single engine of the Dexter, using an approximate steam pressure of 70 pounds, expanded 2·72 to 4·46 times, there was but little difference in economy between an expansion of 3·49 times and one of 4·46 times. We may, therefore, infer that an expansion of five times, under the conditions of these trials, using 80 pounds of steam, in single engines, is as much as can be obtained economically, and that the expansion should be somewhat reduced for a pressure of 70 pounds.

Referring to Table 6 C, it will be seen that, with the single engine of the Dexter, using an approximate steam pressure of 40 pounds ex-

panded 2·08 to 3·34 times, (the latter expansion is the more economical) and that, with the engine of the Dallas, using an approximate steam pressure of 35 pounds, expanded 2·94 to 5·07 times, no loss, but rather a slight gain in cost of indicated power, is shown at an expansion of 5·07 times, as compared with that at 3·89 times—this engine operating, as before stated, very economically at the pressure used. The results at the two expansions last named are, however, so nearly identical, that the cost for the net power (see Table No. 2) is least for the least expansion; considering the experiments on the Dexter and Dallas together, we may conclude that an expansion of $3\frac{1}{2}$ to 4 times is the most economical degree for steam pressures of 35 to 40 pounds.

Referring to Table 6 D, it will be seen that, even with the compound engine of the Bache, operated with an approximate steam pressure of 80 pounds, expanded 4.24 to 16.85 times, a loss resulted at the extreme degree of expansion, and that an expansion of 6 to 7 times appeared to give the best results under the conditions of the trials.

It is not practicable, with the information available (many experiments not having been put in shape for comparison), to calculate accurately the proper rates of expansion for different steam pressures, and it is probable that no fixed rule could be framed to include the modifications due to all conditions. We give the following provisional rule, with tabulated examples:

(6 E.) RULE.—To the number representing the steam pressure above the atmosphere (P) add 37; divide the sum by 22; the quotient will represent, approximately, the proper ratio of expansion (R) for that steam pressure. That is

$$R = \frac{(P+37)}{22}$$

EXAMPLES:

Steam pressure above atmosphere $= P$	5	10	25	40	60	80	100
Ratio of expansion $= R$	1·9	2·1	2·8	3·5	4·4	5·3	6·2

It is probable that these ratios are nearly correct for single engines of large size with details of good design, too large for single engines of ordinary construction, and too small for the better class of compound engines. The rule, though provisional, is safer to follow than the uncertainties of personal opinion, and the variations of actual

practice. Further information cannot vary it materially, for the economy changes very little for expansions considerably greater or less than the most economical grade. The limit of expansion for the higher pressures are apparently well defined by the experiments discussed, but there are indications that there is no loss in using somewhat higher expansions than given by rule for steam pressures of 35 to 40 pounds—of course, however, with results inferior to those obtained by using higher pressures. Further investigations are being made on this subject.

(6 F.) As a general rule, in constructing an expansive engine, too much expansion is attempted and the cylinder is made much too large for the work to be done. This is particularly true in respect to engines designed to be operated expansively with high steam pressures. As previously referred to, the designing engineer, in almost every instance, furnishes too much cylinder to work off the steam from a given boiler at the most economical degree of expansion for the pressure intended. This is one of the most important lessons to be learned from these experiments, and many others as yet unpublished. Nearly all the marine engines constructed have cylinders of sufficient size to develop the power intended with a mean pressure of 25 to 20 pounds, and even lower. These experiments show clearly that it is not economical to expand high pressure steam sufficiently to produce so low a mean pressure, and that with such large cylinders it would be nearly, if not quite as well, to reduce the steam pressure and expansion (as we have complained previously, that the working engineers are in the habit of doing, though to an unwarranted extent). The best results shown by these experiments were obtained with a mean pressure of 34 to 37 pounds, when the boiler pressures were from 70 to 80 pounds, and, therefore, the steam cylinders of non-compound high pressure condensing engines should be not more than two-thirds the size they are usually made. Engines so proportioned would not only work with greater economy, but also with less expansion than those with larger cylinders, so that there would be a more equable pressure throughout the stroke when high steam was used, and less trouble to the engineer. Such an engine, properly constructed and operated, would probably require but about 15 per cent. more fuel than the best form of compound engine to do the same work.

(6 G.) We are now constructing a non-compound high pressure condensing engine, which is fitted with expansive gear, adjustable

only between one-sixth and one-fourth the stroke. To manœuvre the vessel, the cut-off must be thrown entirely out of gear, and distribution of steam effected entirely with main valve. It is hoped that the arrangement will prevent the temptation to reduced expansion, which would take place to an important extent, even when using a cylinder of proper size for the work to be done.

INDICATOR DIAGRAMS.—Annexed will be found specimens of the indicator diagrams taken during the principal runs. Diagrams for each series of experiments on the Bache have been selected with like steam pressures and traced together for facility of comparison.

Hyperbolic curves have been dotted upon one series of the diagrams in such manner as to coincide with the experimental curves near the points of suppression. When the diagrams were taken, the indicators were carefully adjusted so as to be perfectly free in their action, and in some of the diagrams vibrations of the pencil may be observed at the points of cut-off outside the true experimental lines.

The diagrams considered together show a number of differences due to the various changes of condition. As stated previously, the steam supplied by the boilers of the revenue cutters was probably superheated slightly, and the expansion curves on diagrams *F*, *G*, *H*, from their engines more nearly correspond with the Mariotte curves of expansion than the majority of those from the engine of the Bache. The boiler of the Bache was operated much below its power when furnishing steam at the high grades of expansion used (see 4 C), and as the steam room was large, the water level very steady, and extra precautions had been taken to felt the boiler, steam-pipe and valves, the steam supply must have been delivered to the engine in about the same condition as if from a boiler without any superheating surface, or say very nearly saturated or containing but a slight percentage of moisture. The diagrams show, however, that liquefaction rapidly took place when the walls of the cylinder were alternately cooled and reheated as described above, (3 C). When using the single cylinder of the Bache without steam-jacket (see diagram *B*), the expansion curve for bottom of cylinder fell below the Mariotte curve at first, but afterwards rose above it as re-evaporation took place. In the top of the cylinder, however, some water collected, and its re-evaporation during the expansion portion of the stroke caused the expansion curve to rise above the Mariotte curve at all times. At the highest grade of expansion, with and without use of jacket, a loop was found on the dia-

gram from the upper end of the cylinder in two instances (as shown in diagrams *C*), which disappeared upon opening the cylinder relief valve.

These diagrams show that horizontal engines should be more economical than vertical ones, for the reason that when properly constructed, the cylinder can be kept drained at all times.

When using the single cylinder of the Bache, with jacket (see diagrams *A*), the moisture in the steam due to reheating the surfaces was re-evaporated throughout the stroke, causing the expansion curve to rise above the Mariotte curve in most cases. As before, the difference is greater for the top of the cylinder and very large for the shortest suppressions.

With the compound engine of the Bache, the expansion curve for the smaller cylinder which was not steam-jacketed (see high pressure diagrams *D*), also rises materially above the Mariotte curve. The cut-off valve faces were in excellent condition, making leaks improbable, so the difference is doubtless due also to re-evaporation of moisture. The exhaust from the smaller cylinder of compound engine is not so effective in carrying moisture out of the cylinder as in ordinary engines with less back pressure. The slight superheating of the steam on the Rush, together with the steam-jacket, was sufficient to prevent great variation of the two curves (see high pressure diagram *F*).

When the engine of the Bache was operated as a compound engine, without the jacket on the larger cylinder, there was a material reduction of pressure in that cylinder throughout the stroke, as compared with that during the experiments with steam-jackets in use, which may be observed by comparing low pressure diagrams *D* and *E*, and the mean pressures shown in line 25 of Table No. 1.

Superheating.—In conclusion it may be observed that the diagrams taken at the higher grades of expansion on the Bache show such positive evidence of the presence of water in the cylinder (due doubtless, as has been stated, to internal condensation), that it may be claimed that by superheating the steam, the ratio of expansion could be economically increased beyond that shown by the Bache experiments. In discussing this question, however (subject 6), the conclusions were founded on the experiments both with the Bache, where there was probably no superheating, and with the cutters where the

conditions were favorable for the thorough drying of the steam. From both series, and other experiments available, it is concluded that superheating will undoubtedly reduce the final cost, but it does not appear that it will change in a material degree the most economical point of cut-off for a given steam pressure. Superheating should, in fact, show beneficially in the same way as the steam-jacket and in a measure reduce the advantages shown by the latter.

The variations above referrred to between the actual and Mariotte expansion curves, which show, doubtless, the presence of extreme internal condensation, are frequently observed in marine engines using high grades of expansion, and in such cases we may naturally infer, from the whole evidence presented, that there is also a loss of result compared with that obtainable with less expansion. In the experiments with the single cylinder of the Bache, it may be noticed, incidentally, that the expansion curves on diagrams from the bottom of the cylinder correspond closely with the Mariotte curves (particularly with steam-jacket in use), when the engine is working at its most economical grade of expansion, and we have observed a similar correspondence in diagrams from both ends of the cylinder of horizontal engines, where provision was made to drain the water from the cylinder at each stroke.

The Mariotte curve has been used for comparison simply for convenience, without discussing the question whether it is the true expansion curve or not.

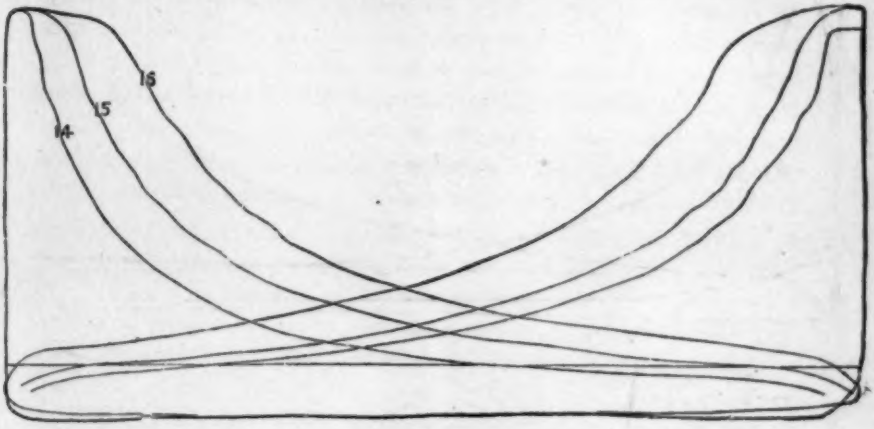
Artificial Hardening of Sandstone.— Manfred Lewin has tried with success in his quarries at Saxonia, and at Neundorf, near Pirna, a process of impregnating sandstone. The stone there quarried is porous and readily absorbs water to a certain depth; it is this fact which renders it possible to introduce a solution to harden the surface. Lewin impregnates the stone with solutions of an alkaline silicate and of alumina; there is thus formed an aluminum silicate within its pores, which gives to the surface considerable resistance. The solutions employed are made with soluble glass and with aluminum sulphate. After the impregnation, the sandstone may be polished like marble, which it then resembles closely. Heated to a high temperature, the exterior layer vitrifies and thus may be colored at pleasure. The coloration may even be obtained simply by mixing the desired pigment with one of the two solutions used for the impregnation.

INDICATOR DIAGRAMS.

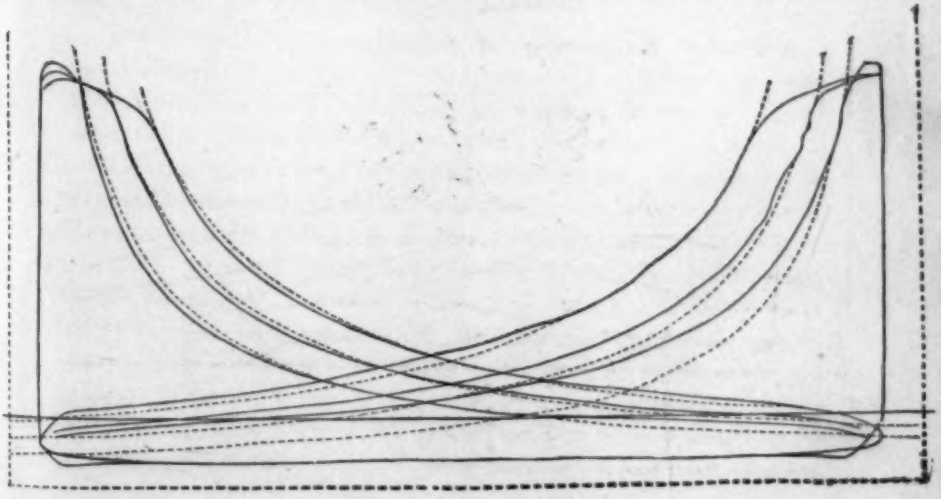
U. S. Coast Survey Steamer "Bache."

The numerals on the diagrams refer to the number of the experiment in Table No. 1.

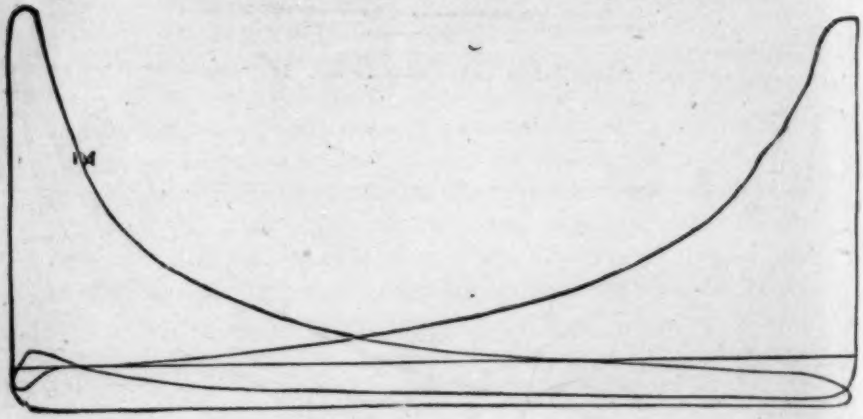
A.—Steamer "Bache." Single Engine, using Steam Jacket. Indicator Scale, 40 lbs. per inch.



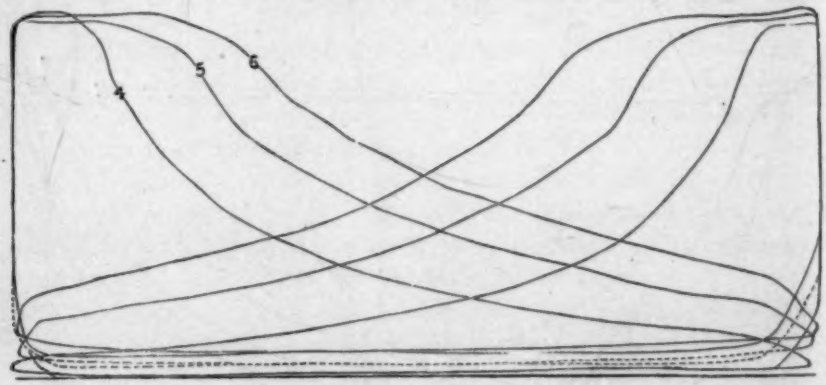
B.—Steamer "Bache." Single Engine, without using Steam Jacket. Indicator Scale, 40 lbs. per inch



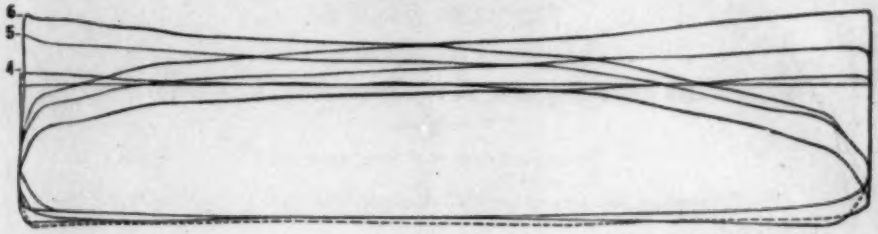
C.—Steamer "Bache." Single Engine, Water in Cylinder. Indicator Scale, 40 lbs. per inch.



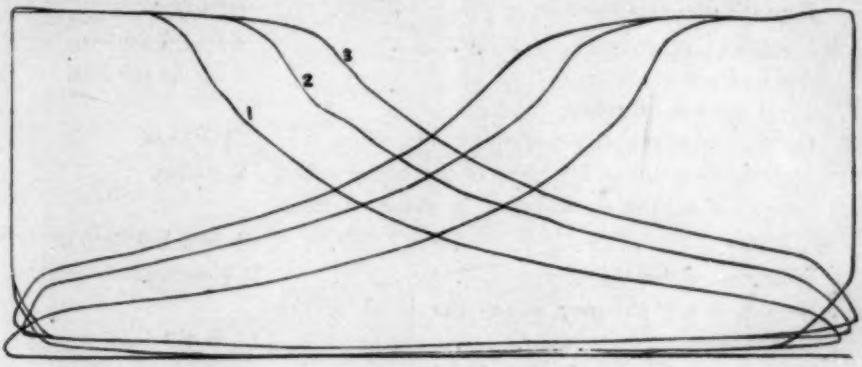
D 1.—Steamer "Bache." Compound Engine, Small Cylinder. Indicator Scale, 40 lbs. per inch.



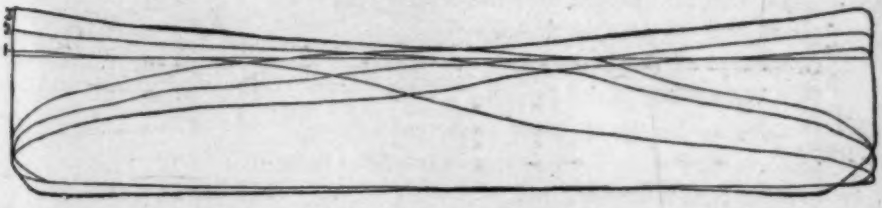
D 2.—Steamer "Bache." Compound Engine, Large Cylinder, using Steam Jacket. Indicator Scale, 16 lbs. per inch.



E 1.—Steamer "Bache." Compound Engine, Small Cylinder. Indicator Scale, 40 lbs. per inch.



E 2.—Steamer "Bache." Compound Engine, Large Cylinder, without using Steam Jacket. Indicator Scale, 16 lbs. per inch.



EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. Isherwood, U. S. N.

[Continued from Vol. lxix, page 285.]

The following are the principal dimensions and proportions of the boiler:

Diameter of the shell,	4 feet 1 inch.
Length of the shell proper,	6 feet 6 inches.
Total length of the boiler, including uptake,	7 feet 7 inches.
Number of furnaces,	1
Breadth of grate-surface,	1·96 feet.
Length of grate-bars,	4 feet 3 inches.
Area of grate-surface,	8·33 square feet.
Total number of tubes,	60
Outside diameter of six of the above tubes,	2¼ inches.
Outside diameter of fifty-four of the above tubes,	2 inches.
Length of all the above tubes, in clear of tube-plates,	4 feet 10¾ inches.
Diameter of the chimney,	10½ inches.
Height of the chimney above the level of the grate-bars,	14 feet 9 inches.
Water-room in the shell, up to 4 inches above tubes,	36·7303 cubic feet.
Steam-room in the shell, above 4 inches above tubes,	11·9404 cubic feet.
Steam-room in the additional cylinder and connecting-pipe,	6·1493 cubic feet.
Total steam-room,	18·0897 cubic feet.
Cross area for draught over the bridge-wall,	1·2370 sq. ft.
Cross area for draught through the tubes,	1·0918 sq. ft.
Cross area of the chimney,	0·6013 sq. ft.
Heating-surface in the furnace,	16·6736 sq. ft.
Heating-surface in the back smoke-connection,	25·2137 sq. ft.
Heating-surface in the tubes, calculated for their inner circumference,	140·3494 sq. ft.

Heating-surface in the uptake,	3·4290 sq. ft.
Total water-heating surface,	185·6657 sq. ft.
Steam-superheating surface in the uptake,	2·5153 sq. ft.
Ratio of the water-heating to the grate surface,	22·289 to 1·000
Ratio of the steam-superheating to the grate surface,	0·266 to 1·000
Ratio of the grate-surface to the cross area over the bridge-wall,	6·734 to 1·000
Ratio of the grate-surface to the cross area through the tubes,	7·630 to 1·000
Ratio of the grate-surface to the cross area of the chimney,	13·853 to 1·000
Weight of the boiler, including grate bars, bearers, chimney, and all doors and plates,	5,050 pounds.
Weight of water in the boiler,	2,290 pounds.

SPACE OCCUPIED IN THE VESSEL BY THE MACHINERY, AND ITS WEIGHT.

The length in the vessel occupied by the machinery, including the fire-room, feed-water tanks, and coal-bunker, is 19 feet 8 inches. The feed-water tanks are placed along each side of the engines and boiler, so that the entire breadth of the vessel is occupied by the machinery and its appendages. The coal-bunker is forward of the boiler.

The weights of the machinery are as follows, namely:

	Pounds.	
Net weight of the engines proper, including crank-shaft, but excluding piping, flooring, etc.,	1,400	
Weight of the stern-bearing pipe in dead-wood, and the dead-wood stuffing-box,	141	
Weight of the line-shafting and its couplings,	590	
Weight of the screw-propeller,	250	
Weight of all the piping,	150	
Weight of the boiler, including grate-bars, bearers, chimney, and all doors and plates,	5,050	
Weight of the water in the boiler,	2,290	
Weight of the felt, lagging, gum, putty and paint on the engines and boiler,	129	
Total weight of machinery,		10,000

	Pounds.	
Weight of feed-water carried in tanks, . . .	8,500	
Weight of feed-water tanks, ...	3,200	
Weight of coal carried in bunker, ...	4,500	
Weight of coal-bunker, ...	600	
Total weight of feed-water and its tanks, and of coal and its bunker, ...		16,800

Total weight of all objects in the engineer department, 26,800 or 12 tons.

SCREWS.

The different screws employed in these experiments are of brass, and will be designated by letters. They are all of the same diameter, and have the same diameter of hub, except the Griffith screw, H.

Screws, A, C, E and F, were formed in the following manner: Two true screws were very carefully swept up in the sand by the same moulder from the same iron guides, and were cast of the same metal at the same time. Each of these screws has two blades, one opposite the other, and is 5½ inches long in the direction of its axis. The pitch is uniform, and, by accurate measurement of the screws after they were cast, 5·136 feet. If the blades are viewed in projection on a plane parallel to the axis, their forward and after edges are parallel to each other, and at right angles to the axis. The outboard end of the screw-shaft was made to receive both screws at the same time, one being placed immediately in front of the other and touching, so that by bringing the after edge of the blades of the forward screw to coincide with the forward edge of the blades of the after screw, the propelling surfaces of both screws would be continuous, and they would thus form one two-bladed screw A, 11 inches long in the direction of the axis. Or, the blades of the after screw could be placed immediately behind those of the forward screw, in the direction of the axis, and they would thus form the Mangin screw F, 11 inches long in the direction of the axis. Or, the blades of the forward screw could be placed at right angles to those of the after screw, and thus form the four-bladed screw E, 5½ inches long in the direction of the axis; for the fact that the blades of the after screw are recessed, as it were, 5½ inches back of those of the forward screw, does not affect the results in the slightest degree, and the screw was the same as

though the four blades had been on the same hub of 5½ inches length. Or, one of the screws could be used alone, when it was the two-bladed screw C, 5½ inches long in the direction of the axis.

After the completion of the experiments with the screws formed as above described, one of them was cut through at right angles to the axis, so as to leave it 3½ inches long in the direction of the axis and make the two-bladed screw D.

By using screw D in connection with screw C, bringing their propelling surfaces to be continuous, the two-bladed screw B was formed 8⅝ inches long in the direction of the axis.

It will thus be seen that all the screws from A to F, both inclusive are composed of exactly the same physical surface, governed by the same co-efficient of friction on the water, and have exactly the same helicoidal form; the results from them are, therefore, free from the doubt which attends trials of screws having different physical surfaces, and, consequently, possibly different helicoidal forms, and different co-efficients of friction, though intended to be exactly the same.

Screw G is a three-bladed screw, with a pitch expanding gradually from 6 feet 6 inches at the forward edge of the blades, to 7 feet 6 inches at the after edge, making the mean pitch 7 feet, which it had by close measurement. The length of the blades, in the direction of the axis, at the periphery of the screw, is 7 inches; gradually increasing, thence to 11 inches length, in the direction of the axis, at the radius of 19 inches; from which point it gradually decreases to 6 inches length, in the direction of the axis at the hub. When the blades are viewed in projection on a plane parallel to the axis of the screw, their forward edge is nearly perpendicular to the axis. If the most forward part of this edge is made to touch this perpendicular, the contact will be at 19 inches radius, from which point the forward edge of the blade curves gradually back until it is, at the hub and at the periphery, 1⅝ inch from the perpendicular. The thickness of the blade just above the fillet joining it to the hub, is 1¼ inch at the center. The weight of the screw is 250 pounds.

Screw H is a three-bladed Griffith screw, formed by trimming the blades of screw G into the Griffith shape, and bolting between them a hub made of wood, to the figure of the frustrum of a sphere 15 inches in diameter and 11 inches in height. This hub was well smoothed, painted, and varnished; its diameter is 0·28846 of the diameter of the screw, and both ends are flat and circular. The

length of the blades, in the direction of the axis, at the periphery of the screw, is 3½ inches, whence they curve gradually outward to the length of 11 inches, in the direction of the axis, at the radius of 19 inches, from which point they curve gradually inward to the hub, at which the length is 7½ inches in the direction of the axis. When the blades are viewed in projection on a plane parallel to the axis of the screw, they are pear-shaped, and the forward and after edges are arranged symmetrically on both sides of a perpendicular to the axis passing through the center of the blades. The pitch expands gradually from 6 feet 8 inches at the forward edge of the blade, to 7 feet 4 inches at the after edge, making the mean pitch 7 feet. The fraction used of the pitch in function of the surface and of the propelling efficiency of the surface is 0·24.

In the following table will be found the principal dimensions of the screws: For screws G and H, the mean pitch only is given, and the slip is always calculated for it. For these screws, too, the length given is the greatest length of the blades in the direction of the axis.

Table containing the principal dimensions of the screws employed in the following experiments.

Designation of the screw.	Diameter, in feet.	Diameter of Hub in feet.	Pitch, in feet.	Number of blades.	Length of each blade in direction of axis, in feet.	Fraction used of the pitch.	Projected area of the blades, on a plane at right angles to axis, in square feet.	Helicoidal area of the blades in square feet.
A	4·3333	0·50	5·136	2	0·9167	0·3570	5·1950	6·1321
B	4·3333	0·50	5·136	2	0·7187	0·2799	4·0730	4·8078
C	4·3333	0·50	5·136	2	0·4583	0·1785	2·0975	3·0661
D	4·3333	0·50	5·136	2	0·2604	0·1014	1·4755	1·7417
E	4·3333	0·50	5·136	4	0·4583	0·3570	5·1950	6·1321
F*	4·3333	0·50	5·136	4	0·4583	0·3570	5·1950	6·1321
G	4·3333	0·50	7·000	3	0·9167	0·3446	5·0140	6·8520
H†	4·3333	1·25	7·000	3	0·9167	0·2034	2·7495	5·2968

*Mangin screw. †Griffith screw.

MANNER OF MAKING THE EXPERIMENTS.

Before commencing the experiments, a very excellent dynamometer was constructed and applied to the screw-shaft for the purpose of measuring the thrust of the screw. It consisted of a single vertical lever, stiff enough not to spring under a considerably greater pressure than the screw was capable of giving, bearing by knife-edges of

steel against a brass ring free to move on guides in the direction of the screw-shaft, and having a turned recess in which was a loose brass ring carrying *lignum-vitæ* plugs or cylinders projecting beyond both sides of the loose ring; both ends of the plugs are bearing-surfaces, and are flat and at right angles to the grain of the wood. These surfaces were kept flooded with oil during the trials. The knife-edges bore against pieces of steel let into the movable brass ring.

The thrust of the screw was delivered against the *lignum-vitæ* plugs by a brass collar secured upon the screw-shaft abaft the regular thrust-collars. There were no collars on the screw-shaft abaft the dynamometer.

The guides of the movable brass ring carrying the loose ring in which the *lignum-vitæ* plugs were inserted, were two steel pins, one on each side of the shaft, fitting into holes of a little larger diameter bored through lugs cast upon the ring.

An accurately graduated steel spiral spring was attached to the upper end of the lever, which end also carried a pencil that traced the line of pressures continuously on a sheet of paper secured around a horizontal large diameter revolving-drum which received its motion from the screw-shaft through worm-wheels and worms. The lower end of the dynamometer lever, the other end of the spiral spring, and the guides of the movable brass ring, were, of course, attached firmly to the vessel. The ratio of the length of the vessel-arm of the lever to the length of the spring-arm, was 1 to 11. The dynamometer-diagram thus obtained, gave the thrust-pressures for every instant during each run of the vessel.

Two indicators were used: one of them was kept permanently in position on one cylinder, and the other on the other cylinder, during the experiments. Each indicator communicated with both ends of its cylinder, and before use was put in perfect adjustment, and had its spring tested.

A counter was attached to the screw-shaft, and registered the number of its revolutions.

The base for the experiments, or the course passed over by the vessel during each run, was a straight line 8,955 feet long, as given by the very accurate survey of Mare Island. It extended from the northern side of the dry-dock dolphins, or guard piers, to the northern side of the magazine wharf. This base was close under the lee of the high ground of the island, the wind over which was always in

the same direction, exactly at right angles to the base; and the water smooth.

During all the trials, the variation in the vessel's draught of water, and in the trim, was very slight. The velocity of the tide varied from nil to three geographical miles per hour.

With each screw eight experiments were made at the speeds, respectively, of 5, 5½, 6, 6½, 7, 7½, 8, and 8½ geographical miles per hour, as nearly as could be obtained. Each experiment consisted of six runs over the base, three in each direction, and the time of making them was selected when the tide had but little influence. The vessel's speed through the water during each double run was not only ascertained from the ranging marks at the ends of the base, but by means of a mercurial speed-gauge consisting of Berthon's modification of Pitot's tube.

This gauge was composed of a glass tube bent into the U-form; the ends of the tube were open, and the curved portion and a portion of the legs were filled with mercury. The top of each leg communicated by a gum pipe with the bottom of a separate air-chamber, and the top of each chamber communicated by another gum pipe with the upper portion of a brass tube closed at both ends. One of these brass tubes was placed within the other, the inner tube passing a few inches through the ends of the outer one by stuffing-boxes. The upper ends of the brass tubes were inside the vessel, and their lower ends protruded about 6 inches below the bottom of the vessel, 12 inches from the nearest side of the keel, and at about the middle of the vessel's length. The inner tube was the pressure-tube, and its interior received the pressure of the water through a hole of 1-32 of an inch diameter in its side, a little above its bottom, and in the directly ahead direction of the vessel. The larger tube was the neutral tube, and in its side, a little above its bottom, was a hole of 1-32 of an inch diameter with its axis at the angle of 41½ degrees from the directly ahead direction. The diameter of the outer brass tube was 1 inch, and of the inner brass tube ⅝ of an inch. A properly graduated scale being attached to the legs of the glass tube, measured by the difference of the level of the mercury in those legs, the vessel's speed in geographical miles per hour. When the vessel was motionless in still water, the mercury in the two legs stood at the same level. The vessel's speed by this gauge in a calm and at dead high or low water, being frequently compared with its speed at the same

time according to the shore-marks, was always found to exactly correspond.

In making the experiments, the vessel, at the intended speed, was brought opposite one end of the base and then run uniformly to the other, being kept in a straight line by an expert steersman. After passing the last end of the base a sufficient distance, the vessel was turned and the run repeated back in the same manner. The throttle-valve was always carried wide open, during the turnings as well as during the runs, and the steam-pressure varied but slightly throughout an experiment, the supply of steam required being always within the capacity of the boiler to furnish.

From the commencement of each run to its end, indicator-diagrams were taken as rapidly as possible from each end of each cylinder. The assistant engineers charged with this duty being very expert, and having the pencils and paper all previously prepared, the diagrams were taken with so little interval of time, that they may be considered continuous. The dynamometer-diagram, taken by another engineer, was continuous from the beginning to the end of the run.

An observer stationed always at the same part of the vessel, gave the signal the instant he was opposite the ranges at the ends of the base; and, at the same moment, two other observers took, one the time to a second, and the other the number on the counter. Thus, the time of making each run, and the number of revolutions made by the screw in that time, were exactly ascertained.

During each run, an observer noted at the end of each half minute the vessel's speed through the water, by the speed-gauge; and at the end of every minute the steam-pressure in the boiler, as given by a spring-gauge. There were also noted during each run, the temperatures of the external atmosphere, of the engine-room, of the feed-water entering the boiler, and of the sea-water; also, the atmospheric pressure as given by an aneroid barometer. Every care was observed in the conduct of the experiments to insure extreme accuracy. Although many of the quantities noted were not necessary to the main purpose of the experiment, yet the results from them are interesting in other points of view.

(To be continued.)

Chemistry, Physics, Technology, Etc.

THE TREATMENT OF TANK OFFAL AND THE GASES FROM RENDERING TANKS.

*With a description of some of the processes in operation in Chicago.**

By Dr. Ben. C. Miller, Sanitary Superintendent.

To sanitarians, and indeed to the citizens of all large cities, the questions how to care for animals, how to kill them, and the proper method of caring for the products of slaughter houses, are exceedingly grave ones; questions that not only concern the health of the community, but the comfort of individuals.

In considering the business of slaughtering and the care of the products, I shall refer to the manner in which it was conducted in Chicago up to 1865, mention the improvements made since that time, and give descriptions of some of the apparatus now in use.

At the period referred to, live stock was received at the different yards in the city; the principal ones being at Twenty-second street. The accommodations were not first class, the pens were not planked in many cases, and the animals were compelled to stand in the mud.

In 1865 the new yards of the Union Stock Yard Company were completed, and the cattle, etc., were subsequently received at that point. The entire yards were drained as well as the nature of the ground would admit, the roadways and alleys macadamized, and the pens for cattle planked; while those for sheep and hogs were in addition roofed to protect them from the weather. Water is furnished throughout the yards from an artesian well. The superintendent, Mr. John B. Shennan, who is absolute in authority, has a large force constantly employed in taking care of the pens and keeping them clean, every effort being made to render the animals comfortable.

Inspectors pass through the yards constantly, and all maimed and diseased cattle found are not permitted to leave, but are killed and sold to a company who own a rendering establishment on the Calumet

* Read before the American Public Health Association, in Philadelphia, November, 1874.

river, some twenty miles from the city, whither the carcasses are taken and rendered for their fat. In this way maimed and diseased animals are prevented from going into the market and being sold for food.

The following table shows substantially the number of animals received during each of the first three years after the opening of the yards:

Hogs, ...	688,140
Sheep, ...	179,880
Cattle, ...	330,301

While in 1873 the receipts were as follows:

Sheep, ...	291,734
Hogs, ...	4,337,750
Cattle, ...	761,428

An increase of 4,199,581.

Previous to 1865 nothing had been done towards the care of gases generated in the rendering tanks. In many houses closed tanks were not in use, the cooking being generally done in open kettles; and when tanks were used, the gases and steam were permitted to escape into the open air, and the offensive odors were carried by the southwest wind over the city. Every year brought to the city a large increase in the number of animals received, and a corresponding increase in the number and capacity of the packing houses, with attendant disagreeable odors. Nothing had been done to utilize the tank refuse when removed from the tanks; the only question was how to get rid of it. Before the river was frozen, boatloads of it were dumped into the lake several miles from shore; and when navigation closed it was buried on the prairies, giving variety to the city smells when the summer warmed it up.

The quantity of tank refuse or offal a single season will yield can be readily estimated when it is known that an ox or a cow gives 50 lbs., a hog 20 lbs., and a sheep 7 lbs. The total amount cared for during 1873 was 22,784,360 pounds.

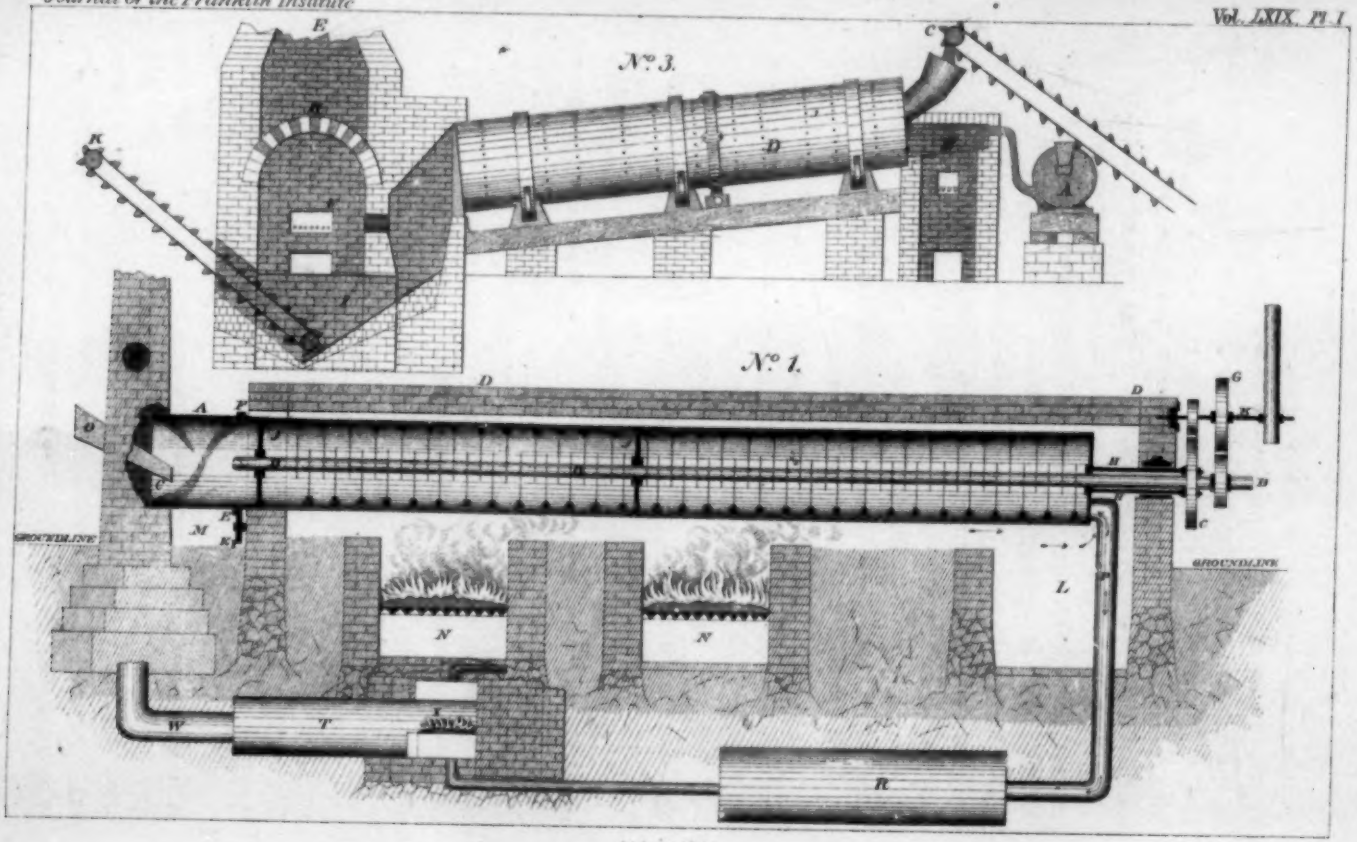
The first effort made toward the disposal of the gases was in the form of a regulation of the Board of Health, compelling the use of tanks from which the steam passed through a coil of pipes into a condenser, and thence, with a portion of the gases, into the street sewer.

This was a marked improvement over the old way, but was not at all satisfactory, since the gases escaped through the man holes in the street sewers into the atmosphere. In some of the houses the steam and gases were passed into the chimneys and thence into the air. This was all that was done in this direction; but steps had been taken to care for the tank refuse.

Baugh's dryer (see Plate No. 1) was procured by one company, and an attempt made to turn the refuse into a fertilizer. It was successful so far as the drying was concerned, but the odors emitted from the smoke stacks were unendurable, and the company's works were indicted as a nuisance.

This drying machine consists of a revolving cylinder thirty feet long and three feet in diameter, inside of which is an axle with three arms or agitators equidistant from one another, which revolve in the same direction as the cylinder. The heat is supplied by several fire places underneath, and also by a current of hot air which passes through the cylinder. When in position that end is highest where the material is fed into the machine; the refuse coming in contact with the agitators and hot air, it is kept constantly in motion until it passes out at the other end in a dry state. The material runs through in about five minutes, and from one to two tons can be dried in an hour. The gases generated during this process pass into a condenser and thence into a chamber (a comparatively new invention), the temperature of which is 2100 degrees. Here they meet a flame and dripping hydro-carbon oil, and, as claimed, are burned, the residuum going up the chimney. My observations of the working of this machine have extended over a period of two years, and in my opinion the dryer cannot be used without giving offense unless the gas chamber is added and kept in perfect order. When not connected with the dryer the volume of smoke and steam passing through the chimney is enormous; when it is used, scarcely any smoke is noticeable, and the disagreeable odor is lessened to such an extent that the drying process can be carried on without giving serious offense.

Another apparatus used at several of the packing houses, for manufacturing the refuse into a fertilizer, is known as Edwards' machine (see Plate No. 2). It consists of a cylinder, varying in size according to the work to be done, with a chamber underneath in which air is heated and passed through an inner plate into the cavity of the cylinder where it comes in direct contact with the material.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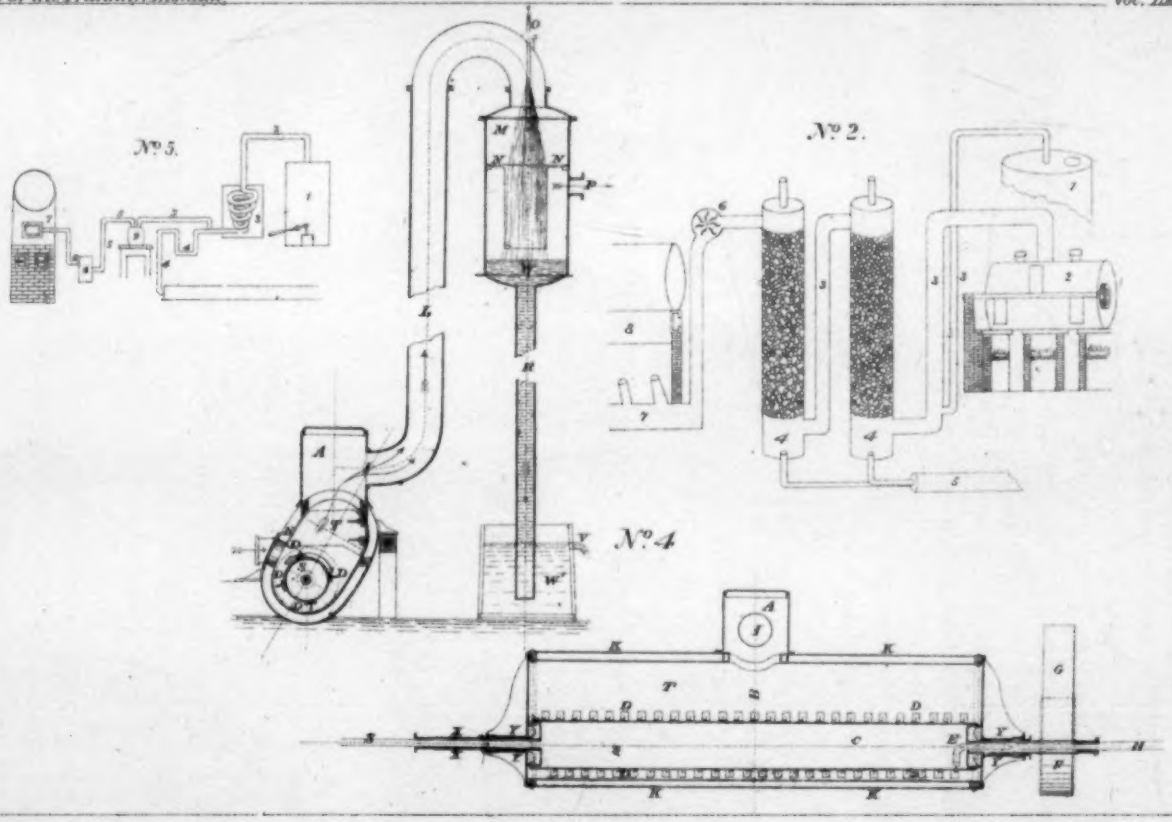

Lith. Sarony & Co. Phila.

In the centre of the cylinder is an axle with extending arms, the axle being revolved by machinery, and keeping the refuse in constant motion. The heat is applied under the cylinder, none entering it except a small quantity which escapes through the openings in the heated chamber.

About one and a half tons can be dried at a charge, taking about three hours. As originally constructed, no provision was made for destroying the gases, which were permitted to escape into the open air. Lately, however, the owners of the machine have attached Bradley's process for destroying the gases, and also added escape pipes to the rendering tanks, those connected with the sewers having been discontinued.

Bradley's process consists of a pipe leading from the dryer and tanks to an upright boiler thirty feet in height, filled with brick so placed that water can percolate freely and escape from the bottom into a pipe connected with the sewer. From the top of the boiler a large pipe leads to the base of a second upright boiler, which is also filled with bricks in the same manner as the other. Extending from the top of the latter boiler is a pipe leading to a rapidly rotating fan which draws the gases and steam from the dryers and tanks and drives them into a chamber underneath the grate bars or furnaces, where they pass through the fire, and, as is claimed, are destroyed. In passing through the boilers, the steam and vapory portion of the gases are brought in contact with a stream of water which flows through the bricks, and are condensed, escaping ultimately with the water into the sewer, the dry gases only being driven under the furnace. I cannot state fully the merits of this machine, as it has been in use only a short time; but that it is a great improvement over the old method there can be no doubt.

Another method is known as Storer's. This dries differently from either of those described. Baugh dries by heat applied externally, hot air passing through the machine; Edwards also applies heat externally, but adds a hot air chamber with openings which allow the hot air to come in contact with the material. In the Storer patent, heat is applied on the inside of the cylinder by using pulverized fuel, the offal coming in contact with a flame and being dried rapidly in a temperature ranging from 2300 to 2700 degrees, the large percentage of water (from 50 to 75 per cent.) preventing it from burn-

ing. This machine (see Plate I, Fig. 3), which will dry about ten tons of raw material an hour, consists of a brick-lined cylinder varying in size according to amount of work to be done, placed on an incline having at one end a fire place and at the other a smoke stack. Underneath are friction rollers, on which it revolves.

The material is fed into the furnace end by an elevator, where it encounters the pulverized fuel, and going rapidly through it comes out at the base of the smoke stack, and there it is conveyed away through another elevator. Passing through such intense heat and drying so rapidly, enormous quantities of steam and gases are evolved. These are carried into a combustion chamber at the base of the stack. This chamber is an inverted cone, perforated, and opens into the smoke stack. At the bottom of the cone is a grate on which is a coal fire. Above the fire, through an opening in the side of the cone, a jet of the pulverized fuel is projected, igniting as it enters and keeping the chamber at a white heat. By the passage of the gases through the chamber and the grate it is claimed that they are destroyed.

This machine has been in operation for two years, and has given general satisfaction. Many experiments have been made to test the thoroughness of the destruction of the gases, and all were very satisfactory, even a wet blanket placed over the smoke stack to dry retaining no odor; and it was demonstrated that if the gases were passed through a sufficiently high temperature, they were neutralized or destroyed.

The latest machine put in operation is known as the Tobey dryer (see Plate II, Fig. 4). It consists of an oblong cylinder twelve or fifteen feet in length, made of boiler iron, and so constructed as to surround the material with a steam jacket. Inside is another cylinder, hollow and some sixteen inches in diameter, covered with teeth, which comminutes the offal and facilitates the drying process. The cylinders are heated by the surplus steam from the boilers used in the packing house proper. The dryer is fed by a contrivance which supplies a given quantity at a time, the material passing through in about ten minutes. On the top of the outer cylinder is a dome, through which the gases pass upward to a pipe leading to a condenser composed of a chamber and a copper pipe with a blind end, perforated with hundreds of minute holes.

The steam and gases entering the chamber come in contact with fine streams of water trickling from the perforations and the steam

part of the gases is condensed, and escapes with the water into the street sewer.

This apparatus has not been long in use and one of its most valuable features seems to be in the economy of working. It can be operated by the surplus steam of a packing house, and its capacity is such that the offal can be disposed of as fast as the fat is removed from it, thus preventing accumulations and permitting no material to grow rancid.

This includes the more prominent machines (with the exception of the Hogel machine which is heated by steam) in use in Chicago for the purpose indicated.

By the use of the above machines the tank refuse can without doubt, be cared for without giving serious offense, but to do so the utmost vigilance is required in working the different processes. That the work will be done without offense to the public, there can be no doubt, for the material is too valuable to lose, and the Chicago public, from the past improvements are satisfied that the work can be done without offense and will insist on its being done so.

In considering the above processes I have spoken incidentally of the escape pipe of the rendering tanks being attached to the Bradley condenser and the destroying of the gases in the furnaces.

It is claimed that the combustion chamber of Baugh or Storer will destroy the tank gases if the proper connections are made.

THE GASES FROM RENDERING TANKS.

After the Board of Health compelled the use of closed tanks and the use of condensers, many experiments were made looking towards the destroying of tank gases.

Among the successful ones was the experiment of Mr. James Turner which resulted in Turner's patent, (Plate II, Fig. 5) which carbonizes the gases and destroys them. After the steam is condensed, the gases are carried off by a pipe to an iron tank, fifty feet from the building where they pass through gasoline or other hydro-carbon oils, and are brought back to the furnace and burned under the boilers. The amount of gases generated from the tanks used in a large packing house is sufficient, after being carbonized, to generate a large quantity of heat, and will by this method save a large percentage of fuel.

That these gases can be burned in the open air without offense has been frequently demonstrated to the writer and others, and at present the patentee is placing a gasometer in connection with his carbonizer

in which the gas will be stored in sufficient quantities to light the packing house.

That each year brings improvements in the packing houses and diminishes the number of nuisances both in quantity and intensity is evident. The packing house of to-day is totally different from that of ten years ago.

Aside from the improvements in caring for refuse and gases, much has been done in other directions. The sewerage is now looked after and every effort is made to have perfect ventilation, both by external windows and by mechanical means of the latest and most approved plans. In the place of wooden floors in the cellars, stone floors have in some of the recently erected houses been substituted.

Packers have learned that the more perfect the arrangements of the house, the more fully sanitary requirements are met, more work can be done and a better class of meat cured.

I think the management of some of the houses has demonstrated that they can be conducted without serious offense, and if in the future improvements progress in the same ratio as they have progressed in the past six or eight years, and packers take an interest in adopting them and doing their work well, there will be slight cause for complaint against packing houses.

New Method of Developing Magnetism.—Tommasi has recently stated in a paper communicated to the French Academy of Sciences, that when a current of steam under a pressure of five or six atmospheres is driven through a copper tube one-eighth to one-quarter of an inch in diameter, wound in the form of a helix, a bar of iron placed in the axis of this helix, becomes so strongly magnetized that a needle placed several centimeters distant from this *steam-magnet*, is decidedly attracted. The magnetism remains in the bar so long as the current of steam continues.

Preservation of Metallic Sodium.—According to Bottger, if sodium be placed in alcohol until its surface becomes brilliant, and then in naphthalic ether chemically pure, and finally in a concentrated solution of naphthaline in naphthalic ether, the metal may be preserved unalterable with its luster unimpaired, for a long time.

ON THE MECHANICAL EQUIVALENT OF HEAT.

By M. Jules Violle.*

The principle of the equivalence between heat and work, we owe originally to Mayer[1]; though Joule also formulated it at about the same time[2]. So important was this discovery that it is not too much to say that it formed the foundation of an entirely new science. Attention was thereby called at once to a principle enunciated twenty years before by Sadi Carnot[3]; and soon the principle of Carnot, generalized by Clausius[4], was united to that of Mayer, to constitute the basis of what is now known as the mechanical theory of heat.

These two fundamental principles, first postulated by Mayer and Sadi Carnot, have modified to a remarkable extent the ideas which were held up to that time, upon the nature of heat. The consequences which have been drawn from them by Helmholtz, Clausius, Joule, Sir W. Thomson, Macquorn Rankine and Hirn, have justly attracted the attention of the entire scientific world; indeed, some of these deductions have already been the cause of introducing important improvements into industrial mechanics. The essential point, however, in the application of these new principles, is obviously the exact value of the numerical coefficient which enters into Mayer's theorem, that is to say, the mechanical equivalent of heat. By this term is meant the number of kilogram-meters (or of foot-pounds) of force which is produced by a unit of heat integrally transformed into work; or, what is the same thing, the number of kilogram-meters (or of foot-pounds) of force which it is necessary to expend in order to produce a unit of heat, assuming that the integral transformation of heat into work is a success. The researches which have been undertaken in or-

[* The following paper, which we translate from the *Revue Industrielle*, was read before the Marseilles Industrial Scientific Society, and is an excellent *resumé* of the whole subject. Its author, M. Violle, is a professor in the scientific faculty at Grenoble.—Ed.]

1. Mayer, *Die organische Bewegung und der Stoffwechsel.* Heilbronn, 1845.
2. *Philosophical Transactions*, 1850, 61.
3. Carnot, *Reflexions sur la puissance motrice du feu*, 1824.
4. *Poggendorff's Annalen*, xciii, 481, 1854.

der to determine this fundamental number are very numerous, especially if we consider how short the time which has elapsed since Mayer for the first time enunciated the equivalence of heat and work.

These researches have been undertaken from widely different standpoints. Indeed it is evident from the great generality of the theorem, that by methods exceedingly diverse, the numerical value of the mechanical equivalent of heat may be accurately obtained. From this most fortunate possibility, therefore, there arises a means of controlling the individual results of each experimenter. In this paper, it is my purpose to enumerate these results, and to specify those which appear to be most worthy of confidence.

The most striking example, probably, of the transformation of work into heat, is that which is furnished by friction. As early as 1798, Count Rumford, struck with the enormous amount of heat set free in the boring of cannon, made an experiment in the Royal foundry at Munich which has since become celebrated. He succeeded by means of the heat alone produced by the friction of a blunt rod against the bottom of a hollow cylinder of iron, in boiling, in the course of two hours and a half, a mass of water of over ten liters[5]. Joule first made an exact measure of the heat set free by friction, and compared it accurately with the work absorbed, in 1849[6]. His experiments, which were very numerous and were conducted with great care, were made with water and mercury, and cast iron, and gave him for the mechanical equivalent of heat the number, 424·9, as the mean of a large number of closely concordant results. The value thus determined, coincided almost exactly with that which Joule had himself determined in 1843, while studying the friction of water in straight tubes[7]. Subsequently, Favre measured, by means of his calorimetric apparatus, the heat evolved in the friction of steel on steel, and thence deduced 413 as the value of the mechanical equivalent of heat[8]. About the same time, Hirn published the results of analogous experiments made by him[9]; the friction of liquids gave him 432, and the compression of lead, 425. It must not be forgotten that all these friction experiments present difficulties which are well nigh insur-

5. *Philosophical Transactions, abridged*, xviii, 286.
6. *Philosophical Transactions*, 1850, 61.
7. *Philosophical Magazine*, III, xxiii, 442, 1843.
8. *Comptes Rendus des Seances de l' Academie des Sciences*, xlvi, 337, 1858.
9. Hirn, *Recherches sur l'equivalent de la chaleur*, 1858, 1.

mountable. The measure of the work done is especially delicate, since all the work expended is not converted into heat; a portion more or less considerable being lost in the form of sensible motion, such as vibrations of surrounding bodies and of the air, without the possibility of measuring it. We should not then be surprised that the numbers obtained in this way, as given above, differ among themselves by the small quantities mentioned.

If in friction, we see an excellent example of the transformation of work into heat, the inverse transformation of heat into work appears more evident still in thermic engines, especially in those which are moved by steam. Hirn has succeeded in measuring with great exactness both the heat communicated to the boiler of a steam engine, and the total work performed by the engine[10]. These experiments, made by means of the powerful steam engines of a spinning factory, near Colmar, cannot, it is evident, lead to an exact value of the mechanical equivalent of heat (Hirn obtained the number 398); but they have a very great importance in establishing and also in popularizing, so to speak, the actual theory of heat.

The steam engine is by no means the only thermic motor employed in the industrial arts. Electro-magnetic engines may also be regarded as thermic machines, deriving their power from the heat evolved by the solution of the zinc in each cell of the battery and transported throughout the circuit by means of the current. The experiments of Favre[11] have shown in a most satisfactory manner that it is at the expense of a certain quantity of this heat that an electro-magnetic engine produces mechanical work; and in measuring the work performed and the corresponding absorption of heat, Favre has obtained another value for the mechanical equivalent of heat, 443. This number, it will be noticed, differs but little from the exact value. It is necessary to remark here also, that these determinations are extremely delicate, and that in the experiments of Favre, the equivalent sought having for its expression the quotient obtained by dividing 131·4 by 0·296, the divisor 0·296 itself being the difference of two quantities of heat measurable scarcely to one thousandth, this difference may very probably have an error of 0·02. This error if admitted would enable us to derive from the data of Favre, the value 435. Again it is possible to deduce the

10. Hirn, *loc. cit.*, 20.

11. *Annales de Chimie et de Physique*, III, xl, 293, 1854.

numerical value of the mechanical equivalent of heat simply by measuring the heat evolved in a wire through which an electric current passes. We know, according to the law of Joule[12], that the heat evolved by a current is proportional to the product of the square of the strength of the current by the resistance of the circuit. Now Clausius has shown that the coefficient of proportionality is the exact reciprocal of the mechanical equivalent of heat[13]. If then, we measure at the same instant the heat which a given current produces, the strength of this current, and the resistance of the circuit, the equivalent sought can be easily calculated. This has been done by Quintus Icilius[14], who making use chiefly of Weber's most valuable researches[15] on the absolute measure of currents, has obtained 392 as the equivalent; a value considerably different from the probable one. The difference, however, does not exceed the limits of uncertainty attaching to the use of the large number of constants which it is necessary to determine, and which themselves are not easy to obtain by experiment.

Instead of having its origin in the chemical reactions taking place in the cells of the battery, the heat produced by electrical currents may be itself the result of a direct transformation of mechanical work. It is this condition of things which takes place when, by the expenditure of a certain amount of work, a conducting wire is moved in presence of a magnet or of a current. The heating which is produced under these conditions, has been measured by Joule, very early in the history of thermo-dynamics, by means of a tube full of water revolving between the poles of an electro-magnet[16]. Indeed by this method the very first determination of the mechanical equivalent of heat was made. The number obtained by Joule, 460, is a remarkably close approximation; although the various values of which this number is the mean are not very accordant, ranging between 322 and 572. This comes, without doubt, from the fact that the measurement of the heat was not made by a method sufficiently exact; that the correction for cooling was a little uncertain; and lastly, from the

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12. *Philosophical Magazine*, III, xix, 260, 1841.
13. *Poggendorff's Annalen*, lxxxvii, 415, 1852.
14. *Poggendorff's Annalen*, ci, 39, 1857.
15. Weber, *Electro-dynamische Maasbestimmungen.* (*Memoires de la Société Royale Saxonne de Sciences, Leipzig*, 1856, *tome* v.)
16. *Philosophical Magazine*, III, xxiii, 263, 434, 435, 1843.

much more important fact that the temperature of the water of the tube was measured by two thermometers placed at the two extremities of the tube, there being nothing to guarantee that the temperature should be the same at all points of the liquid. Indeed it is, on the contrary, much more probable that, with a constant velocity of rotation, a permanent condition of things is established in which the temperature varies regularly from the centre toward the ends. Le Roux has repeated these experiments, making use of the powerful magneto-electric machines of the Alliance Company[17]. He finds for the mechanical equivalent of heat the numbers 442, 462, and 470, the mean being 458. The method employed by him, even, for measuring the heat, is also somewhat uncertain. Foucault had, however, long before, given to Joule's experiment, a remarkable form, in which the heating becomes manifest in a very short period of time.

Between the poles of a powerful electro-magnet, says Foucault[18], I placed the rotating disk of a gyroscope. This disk is made of bronze having a toothed pinion upon its axis, by means of which it was connected with a train of wheel-work, in order to drive it. By means of a crank, worked by hand, a velocity of 150 to 200 turns per second can easily be given to the disk. In order to render the action of the magnet more effective, two pieces of soft iron placed above the bobbins, lengthened the magnetic poles and concentrated the force in the vicinity of the rotating body.

When the apparatus is put in motion with a high velocity, the current of six Bunsen cells passed through the electro-magnet, arrests the rotation in a few seconds as if an invisible brake had been applied. This is really the experiment first made by Arago[19], and developed by Faraday. If now the crank be forced to turn in the attempt to give to the apparatus its former velocity, the resistance encountered requires the application of a certain amount of power, which, disappearing as such, accumulates effectively as heat in the interior of the revolving body.

By means of a thermometer inserted in the disk, we may follow step by step the progressive elevation of the temperature. Having taken, for example, the apparatus at the surrounding temperature of 16° Centigrade, the thermometer was seen to rise successively to

17. *Comptes Rendus des Séances de l'Academie des Sciences*, x, 414, 1857.
18. *Annales de Chimie et de Physique*, III, xlv, 316, 1855.
19. *Annales de Chimie et de Physique*, II, xxiii, 213, 1826.

20°, 25°, 30° and 34°. Then the phenomenon had become so developed as not to require the use of thermometric instruments. The heat produced was sensible to the hand.

Some days afterward, the battery being reduced to two cells, a flat disk made of copper was raised in temperature during two minutes of motion, to 60°.

This experiment is one by which a measurement of the mechanical equivalent of heat may be most admirably made. Two conditions only are necessary and sufficient to make it certain that the heat evolved in the experiment is the exact equivalent of the work expended in maintaining the rotation uniform:

1. It is necessary that the disk should be, at the end of the experiment, in precisely the same condition as at its beginning.

2. It is necessary that the heating of the disk should be the only effect produced.

Both these conditions are satisfied in the experiment.

1. Consider the beginning and the end of the experiment. At these two periods of time, the disk is precisely in the same physical condition, except of course as to temperature and to the other effects dependent upon this. When, then, by immersion in the liquid in the calorimeter, the disk is returned to its initial temperature or to a temperature differing from this by an exceedingly minute amount, it is restored to identically the same physical condition as before the experiment.

2. Leaving the axle out of account for the moment (since its influence upon the result can be estimated without difficulty) the apparatus is reduced to a disk turning freely in the air, without any friction against external bodies, at least, if we except the friction against the surrounding air, which may be regarded as insignificant in consequence of the great mobility of the air and the perfect symmetry of the moving body. If then, the useful work employed in maintaining the rotation be measured, it seems at first sight entirely certain that the heating of the disk is the only phenomenon produced by the observed expenditure.

When, therefore, we consider only the phenomena as they are presented to our senses; when we observe the rotation of the disk maintained by a continual expenditure of force, and notice the gradual heating of this disk during the entire duration of the experiment, the proposition above stated appears to us incontestable. But if we ex-

amine into the matter more closely, a serious objection presents itself to the mind, an objection which Joule himself first suggested (though he formulated it in a very obscure manner), and by which he accounted for the singular disagreement of his experiments with this method. We have, in fact, neglected up to the present time, an intermediate phenomenon; the motion is transformed into heat only by means of electricity. The immediate action of the electro-magnet upon the disk when in motion is to develop in it, by induction, electric currents; and it is these currents which heat the disk. But even if it were true that the work expended to maintain the rotation of the disk was transformed entirely into electricity, is it quite certain that all this electricity is transformed into heat? In order that it may be, it is necessary that the heating of the disk be the only effect produced by the currents. But even if the currents thus generated within the disk do not cause either luminous phenomena or perturbing mechanical effects, have we not to fear that they will give rise to phenomena of induction, thus creating by their influence electric currents in the two polar masses of the electro-magnet? I answer they will not; because I have shown by experiments specially instituted to test this question[20], that as soon as the velocity of the disk becomes uniform, there are no induction currents circulating in polar masses of the electro-magnet, and hence, consequently, there is no reaction between the disk and the electro-magnet. Moreover, these results have since been confirmed by direct experiments made by Jacobi[21]. The reason of this result appears to me entirely obvious; in every experiment, as soon as the disk attains the uniform velocity which is maintained throughout, the electric currents which are developed by induction in this disk, maintain a constant intensity and preserve in space a constant position. We may therefore consider these currents, of the form and distribution of which we have nothing now to say, as absolutely fixed so soon as equilibrium is reached. It is the displacement of the material of the disk with reference to these currents which produces the heating which is observed. But now, if the currents do not change either in strength or in position, there certainly can be no effect of induction produced on external conductors; a conclusion which direct experiment fully confirms.

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20. *Annales de Chimie et de Physique*, September, 1870.
21. *Comptes Rendus des Séances de l'Academie des Sciences*, January, 1872.

In consequence of the facts now stated I was led to the belief that I could employ advantageously Foucault's apparatus for measuring the mechanical equivalent of heat[22]. And by means of it, using disks of various metals, I have obtained with copper 435·2, with tin 435·8, with lead 437·4, and with aluminum 434·9. The experiments made with the disks of copper and of aluminum are, it seems to me, worthy of more confidence than the others, and in consequence I propose 435 as the mechanical equivalent of heat.

The exactness of this number has been confirmed by certain very important researches, made by an entirely different method. From the general properties of gases, we can, it is well known, deduce the value of the mechanical equivalent of heat by means of the formula:

$$E = \frac{a\, p_0 v_0}{C - c}.$$

Now Regnault has made exact determinations of the density, the coefficient of dilatation and the specific heat, under constant pressure, for air, for hydrogen, and for carbonic acid. Moreover, the uncertainty which has so long existed upon the exact value of c, has recently also disappeared, thanks, too, to Regnault, who by a careful study of the propagation of sound through gases, has found for $m = \frac{C}{c}$ the value 1·3945.

I have not space to describe here the experimental processes employed by Regnault in his gigantic investigation on the propagation of sound in gases[23] which has given us this determination of m. I will content myself with giving some of the results, taken from the resumé which the author has himself published:

According to the formula of La Place, the velocity of propagation of a sonorous wave is the same, whatever be the intensity of the wave; but according to the complete theoretic formula, this velocity ought to be as much greater as the intensity of the wave is more considerable. Now, experiment teaches us that in a cylindrical pipe, such as is used for conducting gas or water, the intensity of a wave does not remain constant, but that it successively diminishes; and this the more rapidly in proportion as the tube has a smaller section.

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22. *Comptes Rendus des Séances de l'Academie des Sciences*, June, July, 1870.
23. *Memoires de l'Institut*, (*Academie des Sciences*,) xlvii, 1871.

This fact was observed in all Regnault's experiments; but I shall refer here only to the mean velocity of a wave produced by the discharge of a pistol, which is propagated in dry air at zero, and which can be followed from the moment of starting until the time when it has no longer sufficient intensity to throw into vibration the membranes which indicate its passage. The experiments above referred to were made: 1st, in the Ivry gas main, the interior section of which is 0·108 meter and its length 566·7 meters; 2d, in the main along the military route, whose diameter was 0·300 meter and its length 1905 meters; and 3d, in a large sewer of the boulevard St. Michel, 1·10 meters in diameter and 1590 meters in length.

1. In the main, whose diameter was 0·108 meter, the diminution of the mean velocity of the same wave, reckoned from the instant of its departure, but taken successively over longer and longer distances, and making use of the reflections at the two ends of the tube, is well defined. 2. The mean velocities for waves produced with the same charge of powder, and for equal distances, are much greater in the main of 0·300 meter than in that of 0·108 meter. 3. The mean velocity of propagation in the main, whose diameter was 1·10 meters, diminished less rapidly than in the main, whose diameter was 0·300 meter.

These differences are still more marked when we compare the mean limiting velocities in the three conduits; that is to say, the velocities which correspond to a wave so far enfeebled since its production that it can no longer affect the membranes. For these velocities, the following are the figures obtained: 326·67 meters in the main of 0·108 meter, the total distance traversed being 4055·9 meters; 328·98 meters in the main of 0·300 meter, the total distance being 15240·0 meters; and 330·52 meters in the main of 1·100 meters, the distance being 19851·3 meters.

In all of these experiments, the wave was produced by the same charge of powder. The membranes remained the same in all, and consequently ceased to record in each of the three conduits, when the wave had reached the same degree of enfeeblement. If then the enfeebling of the wave comes only from the loss of *vis viva*, which is communicated to the walls of the tube, the mean limiting velocity should be the same in the three mains since the wave has the same intensity at the instant of starting and precisely the same at the instant when it makes its last mark upon the membrane. These limiting velocities being, on the contrary, very different, it is necessary to

conclude that the walls of the tube exert upon the air in the interior some other action than that just indicated; an action which diminishes notably its elasticity without changing sensibly its density. In order that this action of the walls upon the elasticity of the gaseous medium may be absolutely nil, it is necessary that the tube have an infinite diameter. But it ought still to be very small in as large mains as 1·10 meters; hence, we may say that the mean velocity of propagation, in dry air at the temperature of zero, of a wave produced by the discharge of a pistol, following it from the muzzle of the barrel, up to the instant when it is so far enfeebled that it can no longer throw the most delicate membranes into vibration, is 330·6 meters.

In the experiments made by Regnault at the camp at Satory to determine the velocity of propagation of waves in free air by the old method of reciprocal cannon discharges, he has obtained for the mean velocity of a sonorous wave in free air, dry and at zero, 330·7 meters, a number which coincides almost exactly with the preceding one.

Without insisting here upon the immediate importance of these results, I shall consider now only their utility as bearing upon the question now under discussion. This will appear when we state that the theoretical formula for the velocity of sound in gases, this velocity being once accurately known, enables us to calculate the ratio, $\frac{C}{c}$, which experiment does not give us directly; and hence also to calculate, by the formula above given, the value of E. Employing the numbers obtained in the above experiments of Regnault, calculation gives $E = 436{\cdot}08$.

If now we compare with this value, the number which I obtained by a completely different process, 435, and also that which Edlund[24] had previously deduced by measuring the calorific effects which are produced during the change of volume of metals, 431, it will be very evident that the number generally adopted, 425, is too small and that it is necessary to substitute for it 435 kilogram-meters, as the true mechanical equivalent of heat.

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24. *Poggendorff's Annalen*, cxxxvi, 1865.

DESCRIPTION OF M. KASTNER'S NEW MUSICAL INSTRUMENT, THE PYROPHONE.*

By M. Dunant.

Sound is, in general, according to natural philosophers, a sensation excited in the organ of hearing by the vibratory movement of ponderable matter, whilst this movement can be transmitted to the ear by means of an intermediate agent. Sound, properly called musical sound or tone, is that which produces a continuous sensation, and of which one can appreciate the musical value. Noise is a sound of too short a duration to be appreciated well, as the noise of a cannon, or else it is a mixture of confused and discordant sounds like the rolling of thunder. For a single sound to become a musical sound, that is to say, a tone corresponding to one of the intonations of the musical scale, it is necessary that the impulse and, consequently, the undulations of the air should be exactly similar in duration and intensity, and that they should return after equal intervals of time. In its change to the musical state, however dull and confused the noise may be, it becomes clear and brilliant. Like the diamond, after having been polished and cut according to the rules of art, it has the brilliancy for the ear which the former has for the eye. This is what takes place in singing flames. Very imperfect in its beginning, hoarse, roaring, or detonating, it does not come nearer the musical sound, properly so called in the chemical *harmonica*, as it is termed, still, by means of reiterated trials the sound of the single flame in the tube, the *lumen philosophicum*, as it is elsewhere called, can it be musically produced in every case?

It has long been known that a flame traversing a glass tube under a certain pressure produces a musical sound. The eminent savant, Professor Tyndall, to whom the greater part of the deep questions in physics are no mysteries, has studied singing flames, but it must be admitted that singing flames have only penetrated into the dominion of art in consequence of the discovery made by M. Frederic Kastner of the principle which allows of their being tuned and made to produce at will all the notes of the musical scale, to stop the sound

* A paper read before the Society of Arts, February 17th, 1875.

instantaneously and mechanically; as in keyed instruments the sound is regulated and subdued as desired. It is thus that the modest *harmonica chimique, lumen philosophicum* of natural philosophers has, in the pyrophone, attained to the character of a real musical instrument; this happy result supports the remark that the observation in nature of the phenomenon of sound may conduct man, if not exactly to the invention of music, at least to endow the art with resources which increase its power. The sound of the pyrophone may truly be said to resemble the sound of a human voice, and the sound of the Æolian harp; at the same time sweet, powerful, full of taste, and brilliant; with much roundness, accuracy, and fullness; like a human and impassioned whisper, as an echo of the inward vibrations of the soul, something mysterious and indefinable; besides, in general, possessing a character of melancholy, which seems characteristic of all natural harmonies. The father of this young philosopher, a member of L'Institut de France, and a learned author, who died in 1867, treating on cosmic harmonies, insists on this peculiarity:—

"The harmonies of nature," said he, "which in their terrible grandeur as well as in their ineffable sadness, have ever charmed the philosopher, poet and artist, are most often stamped with a character of vague melancholy, from the influence of which the mind cannot escape. It is especially when the noise of the world is hushed that these powerful harmonies produce the most overpowering and poetical effects."

It characterizes, for example, the sound of the echo, the sound called harmonics, and many others which are included in the range of musical tones, defined further on under the name of *chemical and sympathetic music*. We have the most remarkable examples of these in the sound of the Æolian harp. Science, as well as philosophy, poetry, and musical art, is interested in the further study of these sounds. In Germany, Goethe and Novalis, in France, Jean Paul, and many others, have eagerly appreciated the bond which unites natural harmonies to the most elevated instincts, and to the most ideal aspirations of the human soul.

Professor Tyndall has recognised the fact that in order to render a flame musical, it is necessary that its volume be such that it should explode in unison with the undulations of the fundamental note of the tube, or of one of its harmonics. He also asserts that when the volume of the flame is too great, no sound is produced; he demon-

strates it, by increasing the flow of gas. Professor Tyndall has also called attention to this fact, that in order that a flame may sing with its maximum of intensity, it is necessary that it should occupy a certain position in the tube. He shows this by varying the length of the tube over the flame, but he does not specify the proportions which must exist between the flame and the tube for obtaining this maximum intensity of sound. M. Kastner's merit is in having shown that when two or several flames are introduced into a tube, they vibrate in unison, and produce the musical maximum of sound when they are placed one-third the length of the tube, and if these two flames are brought in contact, all sound ceases directly, a phenomenon M. Kastner demonstrates to be caused by the *interference of sounding flames*. Here is a question, lately scarcely thought of, of which M. Frederic Kastner has determined the laws, at the same time making a most remarkable application of them in creating an instrument which reminds one of, and may be mistaken for the sound of the human voice.

A very simple mechanism causes each key to communicate with the supply pipes of the flames in the glass tubes. On pressing the keys, the flames separate and the sound is produced. As soon as the fingers are removed from the keys, the flames join, and the sound ceases immediately. These new experiments made by M. Kastner upon singing flames should cause all makers of musical instruments to turn their attention to inventions connected with sound. If two flames of suitable size be introduced into a glass tube, and if they be so disposed that they reach one-third of the tube's height, measured from the base, the flames will vibrate in unison. This phenomenon continues as long as the flames remain apart, but the sound ceases as soon as the two flames are united. If the position of the flames in the tube is varied, still keeping them apart, it is found that the sound diminishes while the flames are raised above the one-third until they reach the middle point, where the sound ceases. Below this point the sound increases down to one-fourth of the tube's length. If at this latter point the flames are brought together, the sound will not cease immediately, but the flames will continue to vibrate as a single flame would. M. Kastner, for his first experiments, used two flames derived from the combustion of hydrogen gas in suitably constructed burners. The

interference of the singing flames is only produced under special conditions. It is certain that the length and the size of the tubes depends upon the number of flames. The burners must be of a particular shape; the height of the flames does not exercise much effect upon the phenomenon. From a practical point of view, the numerous experiments effected by M. Kastner during several years, have resulted in the construction of a musical apparatus on an entirely new principle, to which he has given the name of *Pyrophone;* it may be called a new organ, working by singing flames, or rather by vibrations caused by means of the combustion of these flames. This instrument may be constructed from one octave to a most extended compass.

The *British Review* humorously remarks that the pyrophone will naturally be valuable in winter, and that in America it has already been recommended to families as a means of warming small apartments, and perhaps an economical stove may be added to it for the culinary exigencies of straightened households.

The pyrophone will have in the future a poetical mission to fill in the music of concerts. A great number of composers and musicians have already admired this new organ performing by the singing of flames, or rather by vibrations determined by means of the combustion of these flames. They think it will be of great advantage in cathedrals and churches, as the most extended compass can be given to the instrument.

L'Année Scientifique, by M. Figuier, declares that the pyrophone is assuredly one of the most original instruments that science has given to instrumental music. In the large pyrophone which M. Kastner has constructed, and which they have not yet been able to bring to London, an artist can produce sounds unknown till the present time, imitating the human voice, but with strange and beautiful tones, capable of producing in religious music the most wonderful effects. So says *Le Journal Officiel de l'Exposition de Vienne.*

Journals and reviews abroad have unanimously mentioned with praise this new instrument, both from a musical as well as from a scientific point of view.

M. Henri de Parville, in *Les Causeries Scientifiques*, gives a large space to the consideration of "Singing Flames," and states that "gas music" made its *debut* at the Vienna Exhibition of 1873. *La Nature* and *La Revue des Sciences*, edited by M. Tissandier, believe

that this new instrument is destined to produce the most remarkable and unexpected effects in the orchestras of lyric theatres and in large concerts. The chandeliers of the theatre, besides serving to light it, may be converted into an immense musical instrument:—

"When the pyrophone is played by a skillful hand, a sweet and truly delicious music is heard; the sounds obtained are of an extraordinary purity and delicacy, recalling the human voice."

The inventor has prepared a large and beautiful singing lustre, with a dozen or fifteen jets, which can be placed in the richest or most comfortable drawing-room. This lustre may be used at concerts or balls, for it can play all the airs in dance music. It will be worked by electricity, so that the performer who plays may be seated in a neighboring room. The effect will be perfectly magical. The future has other surprises for us, for our houses. The most unexpected applications of scientific principles are daily the result of the skillful efforts of learned men.

Without reckoning Professor Tyndall, who is so well known and esteemed on the Continent, many other learned men, English, German, Austrian, (like Schaffgotsch), and Frenchmen have already studied singing flames, but no one had previously thought of studying the effects produced by two or several flames brought together, till M. Kastner, who, by means of delicate combinations and ingenious mechanism, has produced the pyrophone.

Frederic Kastner, the inventor of the pyrophone, showed from his earliest age a very decided taste for scientific pursuits. His parents, whose fine fortune permitted them to satisfy the taste of their son for study, gave him facilities often denied to genius. They frequently traveled; the first thing which arrested his attention was a railway; this pleased him much; he had a passion for locomotives, just as some children have for horses. He was only three years old when he examined the smallest details with a lively feeling of curiosity. Later on, when he tried to reason and explain his impressions, he overwhelmed with questions those who surrounded him, wishing to learn the mechanism of these great machines, and the mysterious force which sets them at work. But what more especially charmed him was, when the train stopped at the station, the fiery aspect of the jets of gas emerging suddenly from the darkness. At this sight he shouted with delight; such was his enthusiasm that he seemed as if

he would jump out of the arms of those who held him, in order to rush towards the jets of flames, which exercised upon him a sort of fascination.

Steam and gas, in their modern application to locomotion and lighting, were the first scientific marvels which struck the mind and the sense of the child. He studied music under the skillful direction of his father. From the age of fifteen years, in studying gas particularly, his attention was directed to singing flames. The mysteries of electricity were also at this time the object of his study. The researches to which he gave himself up carried him on to invent a novel application of electricity as a motive force. He patented this invention. On the 17th March, 1873, the Baron Larrey, member of the Academy of Sciences of Paris, presented to the *Institut de France* young Kastner's first memoir on singing flames, which laid down the following new principle:—

"If two flames of a certain size be introduced into a tube made of glass, and if they be so disposed that they reach the third part of the tube's height (measured from the base) the flames will vibrate in unison. This phenomenon continues as long as the flames remain apart; but as soon as they are united the sound ceases."

Passing on to his experiments, M. Kastner thus gives his account:—

"I took a glass tube, the thickness of which was $2\frac{1}{2}$ millimeters; this tube was 55 centimeters long, and its exterior diameter measured 41 millimeters. Two separate flames of hydrogen gas were placed at a distance of 183 millimeters from the base of the tube. These flames, while separated, gave F natural.

"As soon as the flames are brought together, which is done by means of a very simple mechanism, the sound stops altogether. If, letting the flames remain apart, their position is altered until they reach one-third of the total length of the tube, the sound will diminish gradually; and it will cease completely if the flames go beyond one-half the length of the tube; under this (one-half the length of the tube) the sound will increase until the flames are brought to one-fourth of the tube's total length. This latter point being reached, the sound will not cease immediately, even if the two flames are placed in contact one with the other; but the two flames, thus united, continue vibrating in the same manner as a single flame would.

"The interference of the singing flames can only be obtained under certain conditions. It is important that the length of the tubes should be varied according to the number of the flames, the height of which has only a limited action or influence over the phenomenon;

but the special shape of the burners is a matter of considerable importance.

"These experiments, which I undertook two years ago, induced me to construct a musical instrument, possessing quite a novel sound, which resembles the sound of the human voice. This instrument, which I term the Pyrophone, is formed by three sets of keys (claviers) disposed in a similar manner to that employed for the conjunction of the organ-key tables; a very simple mechanism causes every key of the different sets to communicate with the supply pipes in the glass tubes. As soon as a key is pressed upon, the flames, by separating, create a sound; but when the keys are left untouched, the flames are brought together and the sound stops."

In consequence of this communication a Commission from the Academie des Sciences de Paris was selected for the examination of this curious invention, consisting of Messrs. Jamin, Regnault, and Bertrand, three distinguished members of that academy, who showed a lively interest from a scientific point of view in M. Kastner's discovery. After fresh experiments, M. Kastner has succeeded in substituting the ordinary illuminating gas for hydrogen gas in working this pyrophone, and his friend, the Baron Larrey, was again the interpreter to l'Academie des Sciences of this new discovery, which much facilitates the employment of the luminous musical instrument. M. Kastner thus expresses himself in his new report presented to the *Institut de France*, 7th December, 1874:—

"The principal objection which has been made to the working of the pyrophone, is the employment of hydrogen gas. From a practical point of view, this gas presents several inconveniences. It is difficult to prepare; it necessitates the use of gas holders, whose size may be considerable. Besides, there is some danger in its use. I have, therefore, given up using hydrogen gas, and for a year I have experimented on the means of applying common illuminating gas to the pyrophone, which is always easy to procure. In the first experiments which I attempted with two flames, with illuminating gas, in a glass tube, I was unable to obtain any sound, which proved unmistakably the presence of carbon in the flames. Whilst the sound was produced in a very clear manner with the pure hydrogen gas, that is to say, without there being any solid foreign matter in the flames, it was impossible to make the tube with illuminating gas vibrate, when placing the flames in an identical condition. It was necessary, then, by some means or another to eliminate the carbon, a result at which I arrived by dint of the following method:—

"When the flame of ordinary gas is examined, and this is introduced into a tube made of glass, or of any other material (metal, oilcloth, cardboard, etc.), this flame is either illuminating or sounding.

"When this flame is only illuminating, that is to say, when the air contained in the tube does not vibrate, it presents a lengthened form, and is pointed at the top. Besides, it swells towards the middle, and flickers on the least current of air. On the contrary, when the flame is sounding, that is to say, when the necessary vibrations for the production of sound are produced in the tube, its form is narrow, and large at the top. Whilst the air of the tube vibrates, the flame is very steady. The carbon in a great measure is eliminated as if by some mechanical process.

"Sounding flames proceeding from lighting gas are in effect enveloped in a photosphere which does not exist when the flame is merely luminous. In the latter case the carbon is burnt within the flame, and contributes in a great degree to its illuminating power.

"But when the flames are sounding, the photosphere which surrounds each of them contains an exploding mixture of hydrogen and oxygen which determines the vibrations in the air of the tube.

"To produce the sound in all its intensity, it is necessary and sufficient that the whole of the explosion produced by the particles of oxygen and hydrogen in a given time, should be in agreement with the number of vibrations which correspond to the sound produced by the tube.

"To put these two quantities in harmony, I have thought of increasing the number of flames so as to increase also the number of the explosions from the mixture of oxygen and hydrogen in the photospheres, and thus determine the vibration of the air of the tube. Instead of two flames of pure hydrogen, I put four, five, six, etc., jets of lighting gas in the same tube.

"I have besides observed, that the higher a flame is, the more carbon it contains.

"I have then immediately been obliged to diminish the height of the flames, and consequently to increase the number so that the united surface of all the photospheres may suffice to produce the vibration of the air in the tube.

"The amount of carbon contained in the whole of the small flames will always be much less than the quantity of carbon corresponding to the two large flames necessary to produce the same sound. In this manner I have been able with separated flames to obtain sounds whose tones are as clear as those produced by hydrogen gas. When these flames, or rather when the photospheres which correspond to these flames, are put in contact, the sound instantly ceases. The carbon of lighting gas, when the flames are sounding, is certainly almost entirely eliminated—in fact, it forms upon the interior surface of the sounding tube at and below the height of the flames a very visible deposit of carbon, which increases whilst the air of the tube vibrates. I can now affirm that the Pyrophone is in a condition to act as well with the illuminating gas as with pure hydrogen. The phenomenon

of interference is produced exactly in the same condition with the two gases, the same flames occupy the same position in the tube, that is the third part of the tube's length measured from the base. In addition to the phenomenon of interference, I believe I shall be able to describe a novel process by aid of which the sound produced by burning flames in a tube can be made to cease.

"Supposing that one or several flames, placed in a tube a third of its height (measured from its base), determine the vibration of the air contained in this tube; if a hole is pierced at the one-third of the tube, counted from the upper end, the sound ceases. This observation might be applied to the construction of a musical instrument, which will be a species of flute, working by singing flames. Such an instrument, from a musical point of view, will be very imperfect, because the sound will not be so promptly or sharply stopped, as when the phenomenon of interference is employed. If, instead of making the hole at the third, it is made at the sixth, the sound will not cease, but it will produce the sharp of the same note. In all these experiments I clearly detected the formation of ozone while flames cause the air in the tube to vibrate. The presence of this body can, moreover, be ascertained by chemical re-agents scientifically known."—Given before the *Academie des Sciences*, 7th December, 1874.

Professor Tyndall, at a lecture on 13th January, at the Royal Institution, showed experiments according to the new principle, with an apparatus of nine flames, which worked during the evening in tubes of different sizes.

Hygroscopic Paper.—Percy Smith has made a series of interesting researches upon the hygroscopic properties of a bibulous paper impregnated with concentrated solution of cobalt chloride. This paper is very sensitive to atmospheric variations, being blue in a dry atmosphere and becoming red when the air becomes humid. He suspended strips of this paper upon the wall of a room opposite a window opening to the south. The window remained open during the day. By the side of the strips were two thermometers, with wet and dry bulbs. Four observations a day were made, and these were continued for a year. The principal results obtained are given in the annexed table, in which the variations of color from red to blue are designated by the numbers 1 to 10. It will be seen that when there was a difference of 13° between the two thermometers, the paper remained entirely blue, and

that it became red only when this difference fell to between 1 and 3 degrees. This fact is easily explained when we remember that the paper once turning blue cannot take a darker tint by any farther diminution of humidity in the surrounding air.

Dates of the Observations.	Dry Bulb Thermometer.	Wet Bulb Thermometer.	Difference.	Coloration of paper.	Remarks.
July 8th, 1st observation,	72	60	12	9	Very warm day.
July 8th, 2d "	74	61	13	10	Very warm day.
July 8th, 3d "	70	59	11	8·5	Very warm day.
July 10th, 1st "	74·5	65	9·5	8	Day warmer than the 8th, blue color less intense.
July 10th, 2d "	77	67	10	7	Day warmer than the 8th, blue color less intense.
July 10th, 3d "	79	67	12	9	Day warmer than the 8th, blue color less intense.
Sept. 30th, 1st "	62	56	6	3	Barometer at rain.
Sept. 30th, 2d "	64	61	3	1	Barometer at rain.
Oct. 1st, 1st "	62	58	4	0·5	Rain during the night. Barometer rising.
Oct. 1st, 2d "	63	59	4	1	Rain during the night. Barometer rising.
Oct. 2d, 1st "	59	55	4	0·5	Barom. falling.
Oct. 2d, 2d "	58	53	5	1	Barom. stationary. Cleared off.
Oct. 23d, 1st "	52	48	4	1	North wind.
Oct. 23d, 2d "	55	54	1	0	West wind.
December 3d,	13	10	3	2	Heavy frost.

From these results, it appears that the absolute temperature of the atmosphere has no relation whatever to the actual color of the paper; the variations of tint being precisely the same for the same differences between the thermometer readings, whatever the actual temperature at the time of observation. Paper impregnated with cobalt chloride solution, may therefore be employed to indicate readily, and precisely the hygrometric state of the air, and thus to control in a very effective way the hygrometers usually employed.

AWARD

OF

Scott Legacy Medals and Premiums.

HALL OF THE FRANKLIN INSTITUTE,

Philadelphia, April, 1875.

Notice is hereby given that the Board of Managers of the **FRANKLIN INSTITUTE** of the State of Pennsylvania, for the promotion of the Mechanic Arts, have in accordance with the recommendation of the COMMITTEE ON SCIENCE AND THE ARTS,

Awarded the Scott Legacy Medal and Premium

To JOHN G. BAKER, of Philadelphia, for Baker's Rotary Pressure Blower;

To HUTCHINS & MABBITT, of Philadelphia, for their Tilting Chair;

And to J. MORTON POOLE & CO., of Wilmington, Del., for their Improvements in Grinding Callender Rollers.

And said Medals and premiums will be delivered to them respectively, unless within three months from this date, satisfactory evidence of the want of originality in said inventions is lodged with the undersigned.

D. SHEPHERD HOLMAN,

April 3t. *Actuary.*